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ANALYSES OF OIL AND GAS FROM DISTILLATION OF RECENT SEDIMENTS.[1]

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INTRODUCTION.

THIS paper is a contribution from Project 4 of the American Petroleum Institute research program. The object of this project is to study the conditions under which sediments that in the future may be source beds of petroleum are now accumulating. As has been described in previous papers,[2] the deposits have been assayed for their potentiality as future source beds by distillation

[1] This paper contains preliminary results of an investigation on "The Origin and Environment of Source Sediments," listed as Project 4 of American Petroleum Institute Research. Financial assistance in this work has been received from a research fund of the American Petroleum Institute donated by Mr. John D. Rockefeller. This fund is being administered by the Institute with the cooperation of the Central Petroleum Committee of the National Research Council.

[2] Trask, Parker D., "Results of Distillation and Other Studies of the Organic Nature of Some Modern Sediments," *Bull. Amer. Assoc. Petrol. Geol.*, vol. 11, pp. 1221–1230, 1927. "Potential Value as Future Source Beds of Petroleum of Several Recent American Coastal and Inland Sediments," *Bull. Amer. Assoc. Petrol. Geol.*, vol. 12, pp. 1057–1068, 1928.

of the dried sediment in half-pint iron retorts. The yield of oil from marine sediments has been small, the maximum being about three gallons per ton (1.2 per cent. by weight). The gas ranges in quantity from seven to sixty cubic centimeters per gram of sediment and is produced continuously throughout the distillation, but above 550° C. increases rapidly in amount. A peculiar black, flocculent precipitate commonly begins to form in the watery portion of the distillate above 550° C. This precipitate settles very slowly in the watery layer and when dried is very light and bulky. At the time the last report was written, this oil, gas, and black precipitate had not been analysed chemically. It is the purpose of this paper to present analyses of some representative samples of these three products. The writers wish to acknowledge their indebtedness to the Chemistry Department of Stanford University, California, for the courtesy of its laboratory facilities in making these analyses.

ANALYSES OF OILS.

Table I. shows the elementary analyses of a few oils from the iron retort distillations. As only a small quantity of oil was available, it was impossible to run duplicates, or even complete the analyses. Except for the sulphur content the oils are similar to each other. The ratio of hydrogen and carbon shown in the

TABLE I.

ANALYSES OF OILS FROM DISTILLATION OF SEDIMENTS.

Sample.	C	H	S	Total.	Other Elements.	Location.	Oil Yield[a]	Sp. G.	H/C[b]
119	79.52	9.54	1.96	91.02	8.98	Algal lake, Fla.	28.0	.935	1.43
166[c]	77.21	10.61	—	87.82	12.18	Florida Bay	2.4	.915	1.64
225	80.48	10.89	7.46	98.83	1.17	Lake Maracaibo	2.4	.885	1.61
A151	68.47	9.13	—	77.60	22.40	Monterey Miocene	5.9	.935	1.56

a Oil yield in gallons per ton.

b Ratio of hydrogen to carbon atoms.

c A limestone-forming sediment. The other three samples contain practically no $CaCO_3$.

last column indicates that the oils are unsaturated. Further evidence of their unsaturation is their increase in specific gravity of .010 to .030 during the several months interval between time of distillation and analysis. Sulphur was plentiful in the two samples tested for it, and since the quantity of undetermined elements in the other two oils was large, it is probable that they also contain considerable sulphur.

ANALYSES OF BLACK PRECIPITATE.

Table II. shows elementary analyses of three samples of the black precipitate. On account of the limited quantity of material available, complete analyses could not be made. The samples are all high in iron and contain significant amounts of hydrogen and carbon. They were not tested for chlorine, but it is possible that ferric chloride is an important constituent, as it volatilizes readily above 550° C. The chlorine for this could be derived from salt resulting from evaporation of connate water during drying of sediments, and the iron from rust from the cans in which the samples are stored, from iron minerals, or from the retort itself.

TABLE II.

ELEMENTARY ANALYSES OF THE BLACK PRECIPITATE.

Sample.	Quantity.	C	H	Fe.	Total.	Other Elements.	Location.
119	56.7 mgm.	15.6	2.2	31.0	48.8	51.2	Lake rich in algae, Fla.
225	26.4 mgm.	15.7	4.8	41.0	61.5	38.5	Lake Maracaibo.
A151	29.0 mgm.	38.6	16.2	33.8	88.6	11.4	Monterey Miocene, Calif.

ANALYSES OF GAS.

General Remarks.—Table III. shows analyses of gas from several types of sediments. The gases were collected in gallon jars over water and represent that portion produced up to the temperature at which sufficient gas had been formed to fill the gallon jar. The more gas produced the lower this temperature was. One sample, No. 149, was analysed in two parts, one representing the portion formed between 20° and 580° and the other, that

between 580° and 660° C. Hydrogen sulphide, carbon dioxide, unsaturated hydrocarbons, oxygen, and carbon monoxide were determined volumetrically by absorption; methane and hydrogen by combustion, and nitrogen by difference. If saturated hydrocarbon gases higher than methane were present, the values for hydrogen and methane would differ somewhat from the figures given in the table.

For purposes of comparison, the gases are separated into three groups. The first consists of only one sample, a deposit from a lake rich in algæ and evidently the mother rock of a rich oil shale; the second, of six rich marine sediments, which however yield considerably less oil than the sample in group one; and the third, of five poor marine deposits, which produce almost no oil. One rich rock of past geologic age, No. A 151, from the Monterey Miocene of California, is included in the second group, and one poor one, No. A 171, from the Pueblo Pennsylvanian of Texas, in the third group.

Results.—The amount of combustible gases varies directly with the oil yield and therefore, inferentially, with the organic content. Not only are the corresponding percentage means for groups 1 and 2 higher than for group 3, but also the total amount of gas produced is greater. Similarly, the readiness with which the gas burned varied with the oil yield. The samples in the individual groups are similar to each other. Even No. A 151, from the Miocene of California and evidently a good source rock for petroleum, and No. 119, the mother rock of a rich oil shale, do not differ materially from each other or from the rich recent marine sediments of group 2. Likewise, No. A 171 from the Pennsylvanian of Texas and apparently a poor source rock, approximates the means for the group of poor recent marine deposits.

Hydrogen amounts to about 25 per cent. of the volume of the gas and is more plentiful than methane, which forms 15 per cent. in groups 1 and 2 and 7 per cent. in group 3. The unsaturated hydrocarbons occur in small quantities in all samples except those from the limestone-forming deposits of Florida Bay and Cuba,

Sample.	H_2S.[a]	CO_2.	US.[b]	O_2.	CO.	H_2.	CH_4.	N_2.	Gas.[c]	Temp.[d]	Inf.[e]	Comb.[f]	Oil.[g]	Location.
Group 1. Future rich oil shale.														

TABLE III.

ANALYSES OF GASES FROM RECENT SEDIMENTS.

Sample.	H_2S.[a]	CO_2.	US.[b]	O_2.	CO.	H_2.	CH_4.	N_2.	Gas.[c]	Temp.[d]	Inf.[e]	Comb.[f]	Oil.[g]	Location.
Group 1. Future rich oil shale.														
119	19.4	4.6	1.3	3.4	15.1	25.3	15.6	15.3	125.0	700	3	57	28.0	Algal Lake, Florida
Group 2. Rich marine sediments.														
A151[h]	0.0	3.0	2.3	7.2	7.1	34.7	29.2	16.5	28.8	600	3	73	5.9	Monterey Miocene.
226	1.3	9.1	2.0	4.3	3.1	35.6	19.5	25.1	19.8	700	3	60	3.2	Lake Maracaibo.
148[i]	—	30.8	45.6	—	—	—	—	—	47.6	640	3	—	2.4	Florida Bay.
149[i]	0.0	7.2	28.8	5.1	8.1	21.8	11.7	17.3	59.5	580	3	70	2.4	Batabano, Cuba.
149[j]	0.0	34.1	3.4	2.7	44.6	7.3	1.9	6.0		660	2	57		
B3	0.0	43.2	0.7	3.1	6.7	21.3	8.3	16.7	24.1	600	2	37	1.3	La Jolla, Calif.
Ave.	0.2	21.3	13.8	4.5	13.9	24.1	14.1	16.3	36.0	630		60	3.0	
Group 3. Poor marine sediments.														
378	0.0	15.4	1.0	4.1	9.4	35.1	4.1	30.9	8.9	650	2	49	0.1	Copalis, Washington
255	8.2	10.7	0.9	4.9	0.2	43.2	4.2	27.7	14.3	700	2	48	0.1	Orinoco Delta.
275	40.0	7.1	0.0	5.7	6.5	13.9	3.9	22.9	23.9	620	1	24	0.1	Baffin Bay, Texas.
284	31.5	29.5	0.3	3.4	0.5	12.2	9.1	13.5	26.0	635	0	22	T	Corpus Christi, Tex.
A171[h]	2.0	22.8	0.4	3.9	0.5	10.8	16.1	43.5	7.0	700	2	28	T	Pennsylvanian, Tex.
Ave.	16.3	19.3	0.5	4.4	3.4	23.0	7.5	27.7	16.0	661		34		

a Also includes SO_2.

b Unsaturated hydrocarbons.

c Cubic centimeters of gas per gram of sediment, on basis of yield to 700° C.

d Final temperature of production of gas represented by analysis. Not final temperature of distillation.

e Degree of inflammability, on scale of 0 to 3.

f Sum of combustible gases, CO, H_2, CH_4 and unsaturated hydrocarbons.

g Oil yield, gallons per ton. Divide by 2.4 to obtain per cent. by volume.

h Sediments of past geologic age.

i Limestone-forming sediments rich in calcium carbonate. Samples 275 and 284 contain small amount; other samples practically none.

j Fraction from 580 to 660° C.

in which they are present up to 46 per cent. of the total volume. Carbon monoxide, likewise, normally is low, forming 6 per cent. or less, but it increases rapidly above 580° C. The production of carbon dioxide is variable, but it averages 20 per cent. of the gas. It also increases rapidly above 580° C. in sample 149, evidently due largely to decomposition of carbonates. Hydrogen sulphide is ordinarily low, but in the samples from the Florida algal lake and the bays of south Texas, it forms 20 and 35 per cent., respectively, of the gas. Although the fresh mud of these samples smells strongly of hydrogen sulphide, it apparently is not an index of richness in the gas, as the limestone-forming sediments of Florida Bay and Cuba, likewise characterized by a pungent odor of hydrogen sulphide, had none in the gas. Nitrogen and oxygen together amount to 20 and 30 per cent., respectively, and occur in the ratio of 4 to 1 and 11 to 2. This suggests air contamination, but evidently most of it occurred after distillation, as due precaution was taken against entrance of air into the retort while the sediments were being distilled.

Change in Gas Production with Temperature.—Sample 149, which was analyzed in two parts, demonstrates changes in gas production that occur about 580° C. Above this temperature carbon monoxide, carbon dioxide, and gas production are much greater, and hydrogen, methane, and unsaturated hydrocarbons are lower than they are below it. Carbon monoxide rises from 8 to 44 per cent., carbon dioxide from 7 to 34 per cent., and gas production from .04 cubic centimeter per gram per rise in temperature of 1° C. to .29 per gram per increase of 1°. Hydrogen decreases from 22 to 7 per cent., methane from 12 to 2 per cent., and unsaturated hydrocarbons from 29 to 3 per cent.

Interpretation of Analyses.—If, for the purpose of ascertaining the relationship of gas to the substances that produce it, the means for the gas from recent sediments, oil shale, cannel and bituminous coal, and even oil sand, as computed from data re-

ported by Fettke,[3] Gavin[4] and Karrick,[5] whose standard method of distillation we have followed, are compared with each other, a general similarity for all these types is observed. Naturally certain differences exist, but they are considerably less than the variation among gases from individual oil shales. Even the change in gas composition with rise in temperature for oil, oil shale,[6] cannel and bituminous coal,[7] and wood,[8] is similar to that noted by us for recent sediments. However, above 500° C. the coals and wood exhibit an increase in hydrogen and essentially no change in carbon monoxide. Consequently, in view of this general similarity of gas from such a variety of sources, it appears that at present it is impractical to attempt to interpret our analyses of gas from recent sediments. Nevertheless, as the gas from the limestone-forming sediments of Florida Bay and Cuba contains a much higher content of unsaturated hydrocarbons than in any sample that has come to our attention, it appears as if the organic matter in these deposits possesses unique characteristics.

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[3] Fettke, Chas. R., "Oil Resources in Coals and Carbonaceous Shales of Pennsylvania," Pennsylvania Geol. Surv., 4th ser., 1923, pp. 97, 98.

[4] Gavin, M. J., "Oil Shale, an Historical, Technical, and Economic Study," U. S. Bur. Mines Bull. 210, pp. 77, 189, 1922.

[5] Karrick, L. C., "Manual of Testing Methods for Oil Shale and Shale Oil," U. S. Bur. Mines, Bull. 249, p. 47, 1926.

[6] Fettke, Chas. G., *op. cit.*

[7] Fieldner, A. C., Private Communication (U. S. Bureau Mines).

[8] Bunbury, H. M., "The Destructive Distillation of Wood," p. 275. Van Nostrand Co., New York, 1923.

EXPERIMENTS BEARING ON THE BIOCHEMICAL REDUCTION OF SULPHATE WATERS.[1]

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INTRODUCTION.

MUCH of the literature dealing with the genesis of ores that are associated with carbonaceous rock is replete with statements attributing the reduction of sulphate solutions to "organic matter." The importance of this mode of precipitation has in many cases been overestimated, and the active precipitant has not been fully appreciated. The past few years have witnessed a growing interest in the activity of micro-organisms in geologic processes, including the reduction of sulphates, and a considerable literature dealing with the results of various investigations has accumulated.[2] Most of the results to date have simply been of a qualitative nature, but they have served as a stimulus to the further study of the series of complex processes that take place in sediments and sedimentary rocks that are inhabited by a symbiotic bacterial flora.

The object of this paper is to present the results of a series of experiments attempting to determine in a quantitative way the effectiveness of bacterial influence in the reduction of sulphates in sediments laden with carbonaceous matter and saturated with natural-occurring sulphate waters.

[1] Financial assistance in this work has been received from the Research Fund of the Graduate School of the University of Minnesota.

[2] Twenhofel, W. H., "Treatise on Sedimentation," Williams and Wilkins Co., Baltimore, 1925. Trask, P. D., "Ore of Mansfeld Kupferschiefer," ECON. GEOL., 20, 746, 1925. Bastin, E. S., "Bacterial Influence on Sulphide Ore," *Jour. Geol.*, 34, p. 773, 1926. Bastin, et al, "The Problem of the Natural Reduction of Sulphates," *Bull. Am. Assoc. Petrol. Geol.*, vol. 10, p. 1270, 1926. Thiel, Geo. A., "Manganese Precipitated by Micro-organisms," ECON. GEOL., vol. 20, p. 301, 1925. "The Relative Effectiveness of Bacteria as Agents of Chemical Denudation. *Jour. Geol.*, vol. 35, p. 647, 1927. "The Enrichment of Bauxite Deposits Through the Activity of Micro-organisms," ECON. GEOL., vol. 22, p. 480, 1927. Lovering, T. S., "Organic Precipitation of Metallic Copper," U. S. Geol. Survey Bull., 795 C. 1927.

TYPES OF ORES INVOLVED.

Bacterial influence in ore genesis is possible particularly in epigenetic sulphide ores associated with sedimentary rocks. This is especially true of such deposits as the copper-bearing sandstones of the southwestern United States or the celebrated copper-bearing shale of Mansfeld in Central Germany. In the sandstone of the Red Beds, atmospheric waters charged with salt and gypsum percolated through the formations and took copper into solution and concentrated it in certain horizons where bacterial decomposition of vegetable matter was in progress. The copper occurs in intimate association with numerous leaves, stalks, and stems of the plant remains.[3] Similar occurrences have been described of copper-ores in the Permian sandstones of Russia.[4] Nodular structures of chalcocite, chalcopyrite and pyrite with plant remains are also reported at New Annon, Nova Scotia.[5] In the Mansfeld shale the ore horizon is characterized by its fauna as a shallow-sea deposit, full of plant remains that were carried in from adjacent shore-lines. "The formation bears the stamp of an organic mud deposit admixed with an organic precipitation."[6]

Many rich deposits of blende and galena associated with organic bituminous shales are also referred to as owing their origin to the reducing effect of the carbonaceous material. Much of the ore of the Joplin district in Missouri and the lead and zinc deposits of the upper Mississippi valley is of this type. Recent investigations indicate that the metalliferous solutions were of an ascending rather than of a descending nature.[7] If the metals in the ascending solutions were in balance with the sulphur radicle, biochemical precipitation would not apply. If, however, any of the solutions were in equilibrium with sulphate, chlorine or bicarbonate radicles, a hydrogen sulphide environment produced by bacterial activity would precipitate the metals.

[3] Weed, W. H., "Nature of Ore Deposits," p. 502.

[4] *Trans. A. I. M. E.*, vol. IX., p. 33, 1881.

[5] Louis, H., *Trans. A. I. M. E.*, vol. XXVI., p. 1051.

[6] Beyschlag, F., "Deutschland's Kalibergbau.," p. 4, 1907.

[7] Emmons, W. H., "The Origin of the Deposits of Sulphide Ores of the Mississippi Valley, ECON. GEOL., vol. 24, pp. 221–271, 1929.

Among gold and silver deposits also, many instances might be cited to illustrate the influence of organic matter contained in sediments, upon the formation of highly concentrated ores. A typical example is the stratum of black shale in the Mono Silver Mine, Dry Canyon, Utah, where large masses of horn-silver and other "high-grade" sulphide ores are associated. Other occurrences commonly summarized in studies of ore deposits are the black Silurian slates of Bendigo, Victoria; the Devonian slates of Gympic, Queensland; the Jurassic slates of the "Mother Lode" region in California; the black shale of Farncomb Hill, Breckenridge, Colorado; and the celebrated Indicator series of Ballarat, Victoria.

NATURE OF CARBONACEOUS MATERIAL IN SEDIMENTS.

The term carbonaceous sediment includes sedimentary deposits containing plant and animal residues in both the original state and the subsequent chemical derivatives.[8] Perhaps the most common carbonaceous rocks are the coals, black shales, and carbonaceous clays. To these should be added the sediments with disseminated or segregated organic matter, in which the quantity of organic debris is in many cases insufficient to be easily detected without chemical or microscopical aid. Furthermore, decomposition products of organic life which have left no carbonized morphological structures are also extremely widespread. Such products are commonly referred to as "humic" decomposition products. Observations of the United States Department of Agriculture indicate[9] a more extensive distribution of organic matter of this type in rocks than has commonly been suspected. The carbonized organic material is generally found in sediments which were deposited under conditions favorable for the preservation of such debris. Fine-grained clastic sediments such as clays and shales are frequently colored with microscopic organic particles of a carbonaceous nature.

The most effective process in the destruction of organic matter

[8] Twenhofel, W. H., "Treatise on Sedimentation," p. 266.

[9] U. S. Dept. Agri. Bulls. 53, 1909, 74, 1910.

in carbonaceous sediments is microbian decomposition. Because of the environmental conditions under which sediments accumulate, the anaerobic bacteria are the most important agents of decay. Some fungi, such as molds, are active both chemically and mechanically, but the extent of their activity is quite limited. Bacteria, however, are present in nearly all natural environments in which a supply of oxygen either free or combined is available for their metabolic processes. With the accumulation and superposition of later sediments the processes of decay are retarded but not entirely suppressed. Such retardation prolongs the period of biochemical decomposition which has been shown to continue throughout long periods of geologic time.[10] As long as decomposition continues, such compounds as CH_4, CO_2, H_2S and NH_3 are produced, and ultimate suspension of decay may be brought about by the development of toxins through the action of the microörganisms themselves; when such a condition is finally reached, the remaining dead organic products are of minor importance in the reduction of meteoric solutions.

EXPERIMENTAL MATERIALS AND METHODS.

The sediments used for experimental purpose in this study were chosen from various environments so as to give a wide range in composition and in degree of bacterial activity. Clayey, carbonaceous, alluvial sediments from the aggraded valley of the glacial River Warren were selected because of their age, which is early post-glacial, and because of the thickness to which they have accumulated. Some of these samples were taken at a depth of 25 feet below the surface of the present floodplain. Two varieties of peat were collected from depressions in the terminal moraine of the Lake Minnetonka district near Minneapolis. The samples of newly-deposited peat were taken from a depth of six feet below the surface of a wet bog. This peat was paired with samples of dry "dead" peat collected from a drained bog where the organic sediments were so completely dehydrated

[10] Bastin, E. S., "The Problem of the Natural Reduction of Sulphates," *Bull. Am. Assoc. Petrol. Geol.*, vol. 10, p. 1270, 1926.

that the vegetative material was crisp and brittle. Still another group of sediments high in lime but laden with vegetative organic matter was obtained from a bog where marl deposition is in progress. A series of samples was selected ranging from slightly calcareous black organic mud to nearly pure marl. The Davis peat sampler was used for getting material from various depths in the bogs. All the samples were taken with the usual precautions observed in bacteriological work.

The solution employed consisted of natural spring water, to which was added 100 cc. per liter of a filtered extract washed from the black mud in the pool of the spring. The extract was added to insure the presence of organic constituents in the solutions. For Series A of the experiment a small amount of ferrous sulphate was introduced and for series B equal amounts of iron and zinc sulphate were added (see Fig. 1). To insure uniformity of conditions all the stock solution was sterilized in an autoclave at 20 pounds pressure for thirty minutes. Analyses for total sulphates made after sterilization showed 2.6 milligrams of SO_4 per milliliter of solution.

Erlenmeyer flasks of 100 cc. capacity were used as containers. The samples were quartered and uniform amounts placed in each

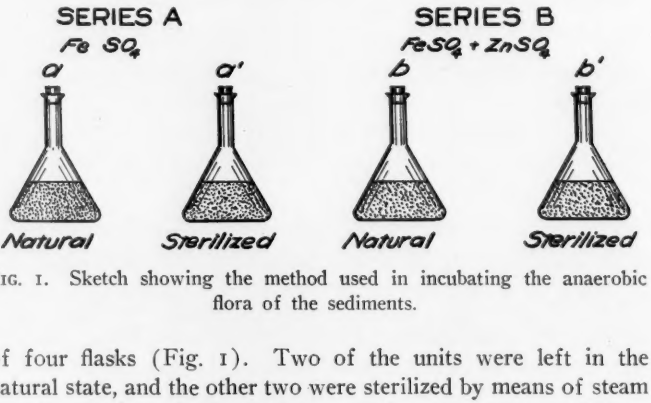

FIG. 1. Sketch showing the method used in incubating the anaerobic flora of the sediments.

of four flasks (Fig. 1). Two of the units were left in the natural state, and the other two were sterilized by means of steam under pressure. The sulphate solutions were then added to

saturate the samples and fill the flasks. In order to insure an environment favorable for an anaerobic bacterial flora, the flasks were closed with rubber stoppers and dipped in sealing wax. Fig. 1 illustrates the nature and arrangement of the two series of experiments. The flasks were kept at room temperature for a

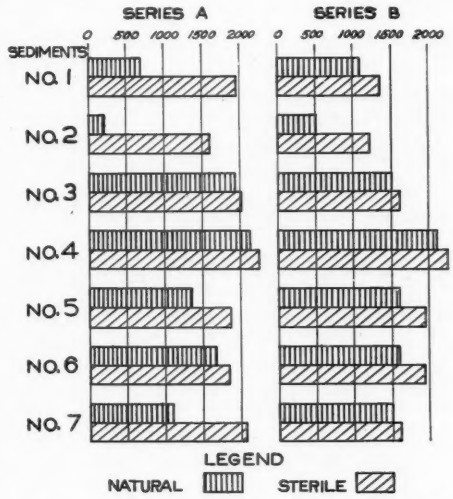

FIG. 2. Table showing the amount of sulphate in solution after a period of 400 days. The control solution contained 2,600 milligrams per liter.

period of 14 months, when the stoppers were removed and 10 cc. of solution withdrawn. The amount of sulphate remaining in solution in each flask was determined by the barium sulphate method. Fig. 2 gives the results of the sulphate determinations.

EXPERIMENTAL RESULTS.

By a comparison of the analytical results obtained from the solutions it is evident that natural, unsterilized, carbonaceous sediments with their normal bacterial flora are more potent agents in the reduction of meteoric sulphate solutions than the same sedi-

ments after biochemical reactions have been suppressed. A difference of 0.3 milligrams per milliliter between two samples is here considered a significant one and is undoubtedly outside the probable limits of experimental error. However, differences of 0.2 mg. or less which amount to less than 0.5 mg. of $BaSO_4$ might be due to error.

No. 1. Floodplain sediments from a depth of 25 feet below the surface.
No. 2. Floodplain sediments from a depth of 5 feet below the surface.
No. 3. Fresh wet peat. Depth 6 feet.
No. 4. Altered, dry peat from drained bog. Depth 3 feet.
No. 5. Black, highly organic, bog mud, slightly calcareous.
No. 6. Same as No. 5, with higher lime content.
No. 7. Post-glacial bog marl, highly calcareous, stained slightly with organic matter.

Samples 1 and 2 represent the same type of floodplain sediment taken at different depths. The bacterial activity of forms that thrive under ordinary conditions of temperature and pressure in the laboratory is much more pronounced in sediments taken from near the surface than in those from a depth of 25 feet. This does not necessarily mean that there is less microbian decomposition at depth, but rather that the organisms from that depth are not as active under decreased pressure conditions. Samples 3 and 4 produced only slight reduction. However, in both cases the nature of the sediment was undoubtedly a factor, since both were composed of peat. The peat of sample 3 was so slightly altered that bacterial decomposition had scarcely reached a stage where a reducing environment was developed. Sample 4, although composed of rotted peat, was so thoroughly dehydrated that it was almost sterile under natural conditions. In this connection it is well to recall that certain varieties of peat in their natural environments are commonly referred to as " sterile bogs " by students of biology.

The last three sediments of the series (Nos. 5, 6, 7) were calcareous. In these cases it should be noted that the sterile sample 7 of series B accomplished nearly as great a reduction of sulphate as the natural sediment. Several factors must be considered in accounting for such similar results. One is the

fact that the percentage of organic residue in the sample was very small and secondly, marl composed of freshly precipitated lime carbonate is an active precipitant of sulphate solutions of heavy metals. Furthermore, zinc sulphate is more susceptible to the action of calcium carbonate than iron sulphate, and consequently the amount of reduction in series B would be greater than in Series A. Zinc solutions permeating the marl, whether natural or sterilized, would react with the lime and the zinc be deposited as carbonate. The replaced calcium would later be deposited as gypsum.[11] It is also highly probable that the freshly precipitated iron sulphide may react upon the zinc sulphate solution and aid in the formation of zinc sulphides.[12] This reaction, however, is more effective at higher temperatures.

NEGATIVE RESULTS WITH "DEAD" ORGANIC MATTER.

A number of observers have reported their failure to obtain the reduction of sulphates with dead organic matter. In most cases the observations were made on isolated organic compounds such as starch, coal, glucose, etc., and not on natural-occurring aggregates that are commonly present in sediments. Allen, Crenshaw and Johnson attempted the reduction of ferrous sulphate with starch and glucose but the results were not promising.[13] Bastin conducted experiments in which marsh gas, hydrogen, and acetylene were kept in contact with solutions of zinc, copper, sodium and calcium sulphates for periods ranging from 60 to 112 days, with no reducing effects. Calcium sulphate and cupric sulphate solutions were also kept in contact with oil shales, crude petroleum, and coal under aseptic conditions, and in no case was there any evidence of the reduction of sulphates. Murray and Irvine found that the black iron sulphide characteristic of the bottom muds of the Black Sea is not formed if sea-water containing putrescible organic matter is sterilized by boiling. They conclude that "the organic matter must be broken down by bac-

[11] Piolti, A., *Jour. Chem. Soc.*, vol. 100, p. 902, 1911.

[12] Stokes, H. N., ECON. GEOL., vol. 2, p. 17, 1907.

[13] Allen, Crenshaw, and Johnson, "The Mineral Sulphides of Iron," *Am. Jour. Sci.*, vol. 33, p. 171, 1912.

teria into its component elements, which in the nascent condition are capable of reducing sulphates to a lower form of combination." [14] M. Plauchud found that calcium sulphate solutions were reduced by living filamentous algae but when the organisms were killed by boiling, the dead organic remains did not produce the same effect.[15]

SUMMARY.

The data presented represent the results of a series of experiments conducted in an attempt to measure in quantitative terms the rôle of bacteria as agents in the biochemical reduction of meteoric sulphate solutions in carbonaceous sediments. In each of seven types of sediments with varying amounts of organic matter, greater reduction was brought about when microbian decomposition was left undisturbed. There was an appreciable amount of reduction in some sterilized sediments, especially those high in lime carbonate.

From the experimental evidence the writer concludes that too much emphasis has been placed on the importance of "dead organic matter" in ore genesis. This applies especially to the ores that are associated with carbonaceous sedimentary rocks. The experiments indicate that at the time of ore deposition the organic matter was still being broken down by bacterial activity into its component parts, which by their mutual interactions were capable of reducing sulphates to a lower form of combination.

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MINNEAPOLIS, MINN.

[14] *Trans. Roy. Soc. Edinburgh*, vol. 37, p. 498, 1895.
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BEARDMORE–NEZAH GOLD AREA, ONTARIO.

GEO. B. LANGFORD.

THIS gold area lies forty-five miles north of the most northerly portion of Lake Superior, and east of Lake Nipigon. The Port Arthur to Longlac branch of the Canadian National Railways crosses the district, thus giving it admirable transportation facilities.

The presence of auriferous quartz was first reported in 1917, by Mr. A. G. Burrows, Ontario Provincial Geologist, who noted a vein near the town of Jellicoe, carrying $4.00 to the ton in gold. In the summer of 1925 prospectors found a promising looking vein near the railway, nineteen miles west of Jellicoe. The news of this find brought about a " rush " in which the country was staked for miles adjacent to the discovery. Before any major deposits had been located, however, the focus of attention was shifted to the newly found Red Lake gold area, with the result that the development of the Beardmore district has been retarded by lack of interest. Nevertheless a limited amount of exploration has been going on in this area since its discovery, and the known deposits are being slowly uncovered.

TOPOGRAPHY.

The topography combines the ruggedness of the Lake Nipigon region and the flat peneplain of the Canadian shield. This is caused by the presence of scattered outliers of the Nipigon Basin diabase sheets, which stand up in bold relief on the truncated folds of the earlier pre-Cambrian rocks.

The bed rock is only partially covered with overburden, and the irregular, rocky surface forms many basins that contain small

lakes and swamps. The only river is the Blackwater, which empties into Lake Nipigon after flowing over a rocky bed with numerous falls and rapids. The erosion by the present drainage is almost entirely confined to the removal of glacial deposits.

GENERAL GEOLOGY.

Summary.—The consolidated rocks are all of pre-Cambrian age. (Fig. 1.) The Keewatin, or basement member, consists of volcanics, plutonics, and a minor amount of sedimentary rock. The igneous rocks of this series are all of basic types, and have been altered until they come under the general name of greenstones.

The Keewatin underwent practically no deformation prior to its being covered by a thick blanket of Timiskaming sediments—conglomerate, iron formation, graywacke and slate. These two series were then compressed into close or fan-shaped folds, whose axes run almost east and west.

Accompanying this folding was a period of intrusive activity during which porphyry and lamprophyre dikes of Algoman age were injected into the Keewatin and Timiskaming rocks. These crustal movements were accompanied by faulting, which opened up fissures and supplied the means of ingress for the silica and gold-bearing solutions to form the auriferous quartz veins.

Following the formation of the veins there was a period of minor intrusion of small diabase dikes. This in turn was followed by an outpouring of Keweenawan diabase, which formed an extensive cap over the earlier formations (Fig. 5).

Erosion had peneplained the original folds of the Keewatin and Timiskaming rocks before Keweenawan time, and since then has removed the larger part of the capping diabase. The present picture is, therefore, a series of truncated folds and intruded dikes, on which rest the remnants of a heavy diabase flow.

Classification.—In the following table the rocks and superficial deposits are classified according to their relative ages, the oldest being at the bottom.

BEARDMORE-NEZAH

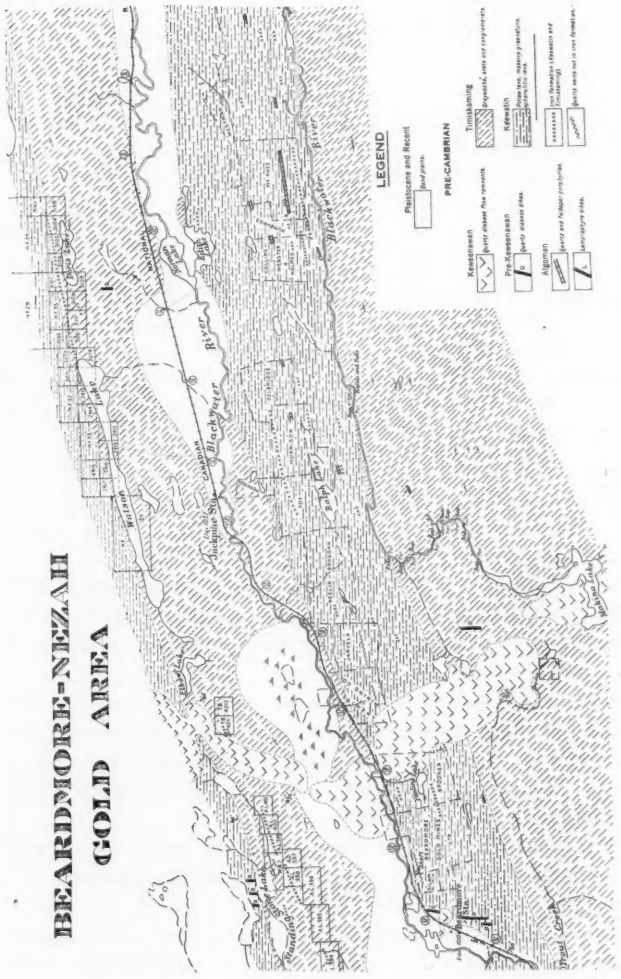

FIG. 1. Map of Beardmore-Nezah gold area, Ontario.

Quaternary

Pleistocene and Recent—muskeg, sand and gravel.
Great unconformity.

Pre-Cambrian

Keweenawan	—diabase flow.
	Great unconformity.
Pre-Keweenawan	—diabase dikes.
	Intrusive contact.
Algoman	—basic dikes, intermediate dikes, acid porphyry dikes.
	Intrusive contact.
Timiskaming	—graywacke, slate, iron formation, and conglomerate.
	Unconformity.
Laurentian	—granite intrusions in adjoining areas to the north—represented in this area only by boulders in Timiskaming conglomerate.
	Intrusive contact.
Keewatin	—pillow lava, massive lavas, intrusives, iron formation, and rusty weathering carbonate.

Keewatin

This series forms two prominent bands across the area, where erosion of the anticlinal folds has uncovered the basement rocks. Some small lenticular outcrops occur under similar structural conditions at the east end of the area.

Metamorphism of the Keewatin has been so pronounced that many of the original characteristics of the rocks have been completely changed. Approximately 90 per cent. of the series is made up of igneous rock, the remainder being sedimentary iron formation and rusty weathering carbonate.

The igneous rocks are all basic, and come under the general name of greenstones. They have been subdivided into the following groups:

Ellipsoidal or Pillow Lava.—This is the most easily distinguished volcanic of the Keewatin series because of the well-marked ellipses formed by the partially eroded pillows. Individual pillows usually comprise a core and two concentric layers. The core consists of meta-basalt, covered by a shell of amygda-

loidal or spherulitic rock, which in turn is surrounded by a layer of chloritic material which may be the remains of a devitrified glass. These pillows often show a flattened side towards the bottom of the flow.

Massive Lavas.—Lava flows devoid of pillow structure are of frequent occurrence. The only way to distinguish such rocks as volcanics is by means of their brecciated flow tops, which consist of angular fragments of amygdaloidal rock held in a matrix of meta-trap. Otherwise they are massive with textures varying from felsitic to porphyritic.

The most markedly porphyritic of the lavas occurs south and southwest of Nezah. It consists of large crystals an inch or more in diameter embedded in a chloritic schist. Contact goniometer measurements and microscopic examination demonstrated that these crystals were original plagioclase, now almost completely saussuritized.

Plutonic Rocks.—Massive greenstones, devoid of any flow structure, are common in the Keewatin. Occasionally an intrusive contact can be identified, showing that some, at least, of such rocks are not volcanics. As in the case of the preceding types, little information is to be found in microscopic slides relative to the nature of such rocks. Chlorite, serpentine, zoisite, carbonates, epidote, sericite, secondary plagioclase, and quartz are the common constituents, and their relative proportions indicate that these were originally basic rocks.

Whether these intrusives should be placed in the Keewatin is an open question. They have been tentatively classified as a part of the Keewatin igneous activity until such time as they have been studied in greater detail.

Keewatin Sedimentary Series.

Interbedded with the volcanic rocks are two small sedimentary series which are usually found closely associated. One, a true sediment, is the type generally referred to as iron formation, and the other is a rusty weathering carbonate. The best exposure of these rocks was seen in the central greenstone mass.

Iron Formation.—The beds of iron formation average about twenty feet thick, and are composed of alternating iron-free, and

iron-bearing laminæ (Fig. 2.) Seen under the microscope the iron free layers consist of well sorted and recrystallized quartz grains, with few impurities. (Fig. 3.) The ferruginous layers, which contain a large percentage of quartz, have been recrystallized and metamorphosed, and the iron now occurs in such minerals as magnetite, pyrrhotite, actinolite, and chlorite cemented in crystalline quartz.

In places the metamorphism has been so complete that the iron

FIG. 2. Slab of Keewatin iron formation one-half natural scale. The dark laminae are iron-bearing and the lighter ones are practically iron-free. Photo by B. M. Shaub.

formation bed has the appearance of a banded vein, mineralized with pyrrhotite and magnetite, and consequently has misled prospectors in this area who were unacquainted with these actinolite-magnetite-quartz rocks.

According to Van Hise,[1] such rocks were originally sediments composed of the carbonates of calcium, iron and magnesium, with some silica, and were subsequently metamorphosed into actinolite-magnetite-quartz rocks.

Rusty Weathering Carbonate.—Throughout the central area of the Keewatin rocks and usually near the sedimentary iron

[1] Van Hise, C. H., "A Treatise on Metamorphism," U. S. G. S. Mon., 47, pp. 834–842.

formation are greenstones carrying sufficient iron-calcium-magnesium carbonate to produce a rusty looking surface on weathering.

Microscopic analysis did not assist in determining the origin of these rocks as no criteria could be found to determine whether they were impure metamorphosed sediments or highly altered igneous rocks. In most cases the recognizable minerals—chiefly

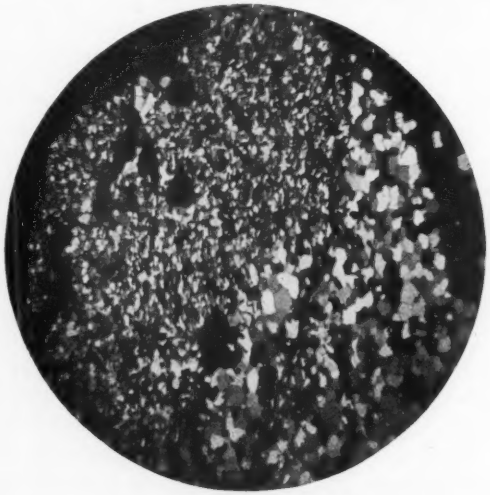

FIG. 3. Photomicrograph of a quartzite layer of Keewatin iron formation. The quartz grains are of two sizes, but each size is confined to a distinct and well sorted layer.

quartz, carbonates and feldspar—were embedded in a matrix that was too fine-grained to be identified.

Although the microscopic evidence is not conclusive, the field relations together with the possibility of carbonates of iron, magnesium and calcium having been precipitated as part of the sedimentation which formed the iron formation, suggest that these rusty weathering carbonates owe their origin more to sedimentary

than to igneous processes. Coleman (4) [2] and Wilson (11) [3] also suggest that these carbonates are of sedimentary origin.

Laurentian.

No intrusives of this age were found in the area. The only evidence of Laurentian igneous activity is in the plutonic rock types found in the Timiskaming conglomerate.

Timiskaming.

The Timiskaming age contributed a thick sedimentary series which now has a greater areal distribution than the Keewatin. It has suffered the same folding as the greenstones and occupies synclinal troughs between the greenstone areas. The dip of the sediments is nearly vertical. The series consists of graywacke and gray slate, iron formation interbedded with black slate, and conglomerate.

Conglomerate.—Immediately north of the Beardmore-Nezah area there is a sedimentary series of rocks with a basal conglomerate which Moore (7) [4] has described, placing the conglomerate in the Lower Huronian and giving the series the local name of Windegokan series. Some time was spent in trying to correlate the Windegokan and the Timiskaming sediments, and by tracing one into the other they were demonstrated to be of the same age.

The conglomerate, which is fairly thick in the north part of the area, becomes thinner towards the south and is almost absent in the vicinity of Blackwater river. It is composed of cobbles of granite, greenstone, carbonate schist and jasper embedded in a fine-grained greenish-gray matrix.

Iron Formation.—Coleman (4) [5] has described the three well defined iron ranges which are found in the area east of Lake Nipigon. Of these three ranges only the southern one lies within the Beardmore-Nezah area.

[2] P. 24. Numbers given in parenthesis refer to the appended bibliography.
[3] P. 45.
[4] Pp. 146–147.
[5] Pp. 113–114.

This iron formation occupies a definite horizon in the Timiskaming sediments a short distance above the conglomerate, and both have much the same areal distribution. The strike of the former is approximately north 75° east over its entire length, and the dip is vertical or slightly to the south.

The iron formation is composed of alternating black slate and iron-bearing laminæ; the latter consisting of magnetite and hematite in a granular silicious matrix, or jasper.

The origin of this type of iron formation was the subject of much investigation by Moore,[6] who did detailed work near Onaman Lake, which lies to the northeast of the Beardmore area. The iron formation in the two areas is so similar that Moore's theory of origin is applied to the Timiskaming iron range in the Beardmore-Nezah area, namely, that the original deposition was an intimate mixture of iron carbonate and chert, with some bog iron. These were metamorphosed respectively into magnetite or hematite, crystalline silica, and hematite; or by a combination of the last two to make jasper.

Graywacke and Slate.—The graywacke and slate which form the bulk of the Timiskaming series are the usual gray-colored, banded, fine- to medium-grained clastics that commonly make up the rocks of this age. The graywacke bands vary from a fraction of an inch to several feet in width, and where wide, the rock is often quite massive without much trace of bedded structure. The slate is a fine-grained rock, in places showing a slaty cleavage, and always occurs in relatively narrow layers that show good bedded structure. The graywacke may be sufficiently coarse-grained to permit of the recognition of its constituents in a hand specimen. Such rock consists of fragmental quartz and plagioclase, with some secondary biotite, in a fine-grained matrix.

In travelling south from the central greenstone area one is impressed by the increase in the amount of biotite which occurs in the graywacke and slate. This change is not entirely gradational, as highly micaceous bands are commonly interbedded with other bands which are relatively free from mica. In some places there

[6] Moore, E. S., "Geology of Onaman Iron Range Area," Ont. Bur. Min. Ann. Rept., vol. XVIII., pt. 1, 1909.

is sufficient mica present to place the rock in the category of the mica gneisses.

Microscopic examination reveals that the biotite is developing at the expense of the cementing matrix of the graywacke, and in some of the specimens examined it constitutes as much as two to three per cent. of the entire rock. The mica scales do not show any evidence of being detrital material, as none of them are bent or bleached, nor do they have " frayed out " edges. Under high magnification they are seen to contain inclusions of quartz and feldspar, and occasionally are surrounded by a mosaic of recrystallized quartz. The latter condition is probably due to excess of silica above that required to form biotite, which migrated to the outer rim of the growing crystal. Most of the specimens examined show that the mica flakes are fairly well oriented, but no more than would be expected, since the matrix from which they developed was distributed in layers.

The origin of this biotite is thought to be due to the recrystallization of the matrix of the graywacke, by heat supplied from deep-seated igneous rocks. No balanced chemical equation can be written to express the changes which took place, because the composition of neither the biotite nor the matrix is known. The matrix, however, does contain chlorite and sericite, and these minerals contain all the elements necessary to form biotite. Although they themselves are secondary, they give some clue to the chemical composition of the matrix. Metamorphism is thought to be due to igneous heat rather than that developed by orogenic movements. It is known that a large granite mass outcrops about seven miles south of the Beardmore-Nezah area, and it is thought that these mica gneisses form the outer rim of the aureole of the contact-metamorphic rocks. This idea is supported by the fact that these micaceous rocks are found only in the southern area of Timiskaming sediments, and the degree of metamorphism is more marked farther to the south.

Algoman.

The Algoman is represented by a series of relatively small dikes ranging in chemical composition from basic to acidic, and

occurring in a roughly elliptical zone with the long axis of the ellipse parallel to the strike of the Keewatin anticline. This ellipse is roughly 19 miles long by 2½ to 3 miles wide, with its centre in the central greenstone mass southwest of Nezah. Near the centre of this zone are the acid rocks and it is here that there is the greatest number of dikes. The intermediate and basic rocks are few in number and are found near the periphery of the elliptical area.

Acid Porphyries.—Acid intrusives make up over 95 per cent. of the Algoman rocks. They are light-colored and where the dikes are more than three or four feet in width, are markedly porphyritic. Variations in the chemical composition, or the conditions prevailing at the time of consolidation of the magma have given rise to mineralogical variations. Either quartz or feldspar may form the predominant phenocrysts, although feldspar porphyry is the prevailing type. Ferromagnesian minerals are present in exceedingly small quantities and almost without exception have been altered to chlorite and serpentine. The only sulphide seen was pyrite, and it is rare. Weathering has caused marked alteration of the feldspars, with the result that they are always well sprinkled with minute sericite flakes, and are usually quite cloudy.

Intermediate Intrusives.—Only one dike of this nature, a quartz monzonite, was found, and although it cannot be said to represent any group of rocks yet it demonstrates that differentiation took place in the Algoman magma. The microscopic examination showed this rock to contain more ferromagnesian minerals than any of the quartz or feldspar porphyries. The bulk of the rock is fine quartz and feldspar (orthoclase and plagioclase) which forms a matrix for fair amounts of idiomorphic hornblende and a little biotite.

Basic Intrusives.—Two basic dikes were found which, for convenience, have been called lamprophyre. One consists of actinolite, pseudomorphs of biotite after hornblende, interstitial quartz, a little oligoclase or andesine and secondary calcite. The other is an amphibolite, and consists principally of hornblende, some

biotite, secondary calcite and chlorite, with a very small amount of plagioclase.

It is apparent that dikes such as the above two types consolidated from a magma which was distinctly different from that from which the acid porphyries crystallized. These facts suggest that the Algoman magma differentiated, and practically all the ferromagnesian minerals were segregated to form basic or intermediate rocks. The residual magma was highly silicious, and after consolidating to form quartz and feldspar porphyries there was left a considerable quantity of silica which was later injected to form quartz veins.

Pre-Keweenawan.

Occasional and small diabase dikes with a north strike are found throughout the area. They are distinctly younger than the Algoman and older than the Keweenawan, and have been classified merely as pre-Keweenawan.

FIG. 4. Polished specimen of pre-Keweenawan diabase showing the porphyritic nature of this rock.

The crystallization of the minerals in these dikes ranges from almost felsitic to very coarsely porphyritic, and is usually found to vary directly with the width of the dike. A polished specimen of diabase porphyry is shown in Fig. 4, in which the large feldspar crystals are conspicuous. These feldspars show marked

zoning, the centers of the phenocrysts being medium labradorite, and the outer rim andesine. The matrix is medium-grained quartz diabase.

Keweenawan Diabase Flows.

The Beardmore area forms a part of the Nipigon basin, in and around which is one of the largest trap-covered areas in the Canadian Shield. These sheets and sills of diabase occur at or near the top of the pre-Cambrian succession, and in the area between Port Arthur and the transcontinental line of the Canadian National Railways they cover approximately 6000 square miles.

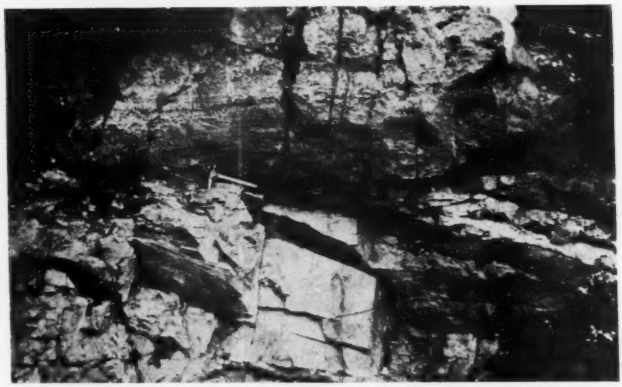

FIG. 5. View of the Keweenawan-Keewatin contact. The hammer lies along the contact. The overlying diabase shows a faint columnar jointing, in contrast to the inclined jointing of the underlying greenstone.

Wilson (11) [7] considered these sheets of cap rock to be partly flows and partly sills. Some of the later investigators in this area are inclined to doubt the volcanic origin of these rocks; however, it was conclusively proved that the capping diabase of the Beardmore area is volcanic. The diabase occurs as isolated hills which commonly rise 200 to 300 feet above the general level of the area.

[7] P. 78.

They are flat topped with cliff faces on the eastern sides and gentle slopes on the western side. Their only economic interest lies in the fact that they may cover important quartz veins.

FIG. 6. Photomicrograph of Keweenawan diabase showing good ophitic texture.

Pleistocene.

The deposits left by the retreat of the glaciers are mostly of the glacio-lacustrine type. Nowhere was any boulder clay identified, but sand and gravel deposits are of frequent and, in places, extensive occurrence. The latter types are thought to have been deposited under the waters of Lake Algonquin.

STRUCTURE.

The Keewatin rocks suffered little deformation prior to the deposition of the Timiskaming, as there is a structural discordance of only five degrees between these two series. The Keewatin and Timiskaming, however, were subjected to heavy

compressional forces acting along a north-south line, with the result that these rocks were folded into synclines and anticlines whose axes run north 75 degrees to 85 degrees east. This folding was so severe that fan-shaped folds were developed, as is shown by the manner in which the rocks dip toward the axis of the anticline. Figures 7 and 8 illustrate and explain the nature of the folds.

A period of faulting followed the folding, the faults being

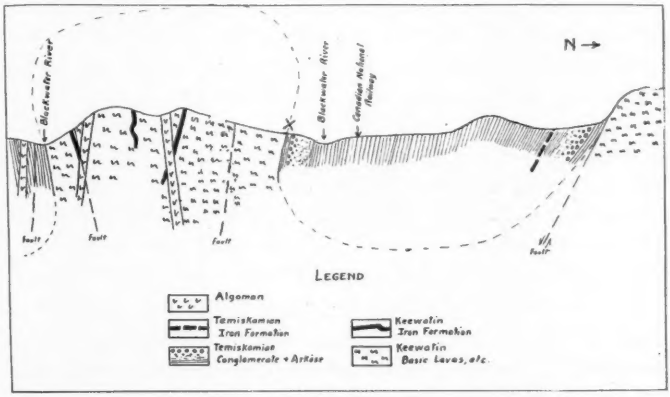

FIG. 7. Generalized north-south structure section across the Beardmore area in the vicinity of Nezah. The actual conditions as found at the contact "X" are shown in Fig. 8.

practically all strike faults. This fracturing followed closely after the intrusion of the Algoman dikes, since the dikes have been cut by the faults, and the fissures so formed filled by vein quartz.

The only crustal disturbances which have taken place since the late Algoman period are a minor amount of faulting in a northeast direction, and the intrusion of the pre-Keweenawan diabase dikes. Both of these events post-date the quartz veins. One fault of this age was seen, and it cuts a quartz vein with a horizontal displacement of 50 feet. In the case of the diabase dikes, no relative movement of the walls was in evidence.

ORE DEPOSITS.

Iron.

The Timiskaming iron formations are the only ones which have been looked upon as holding forth any economic possibilities. Prior to 1908 they were investigated by surface exploration and diamond drilling. Prospecting was carried on over practically the entire length of the iron band in the Beardmore-Nezah area,

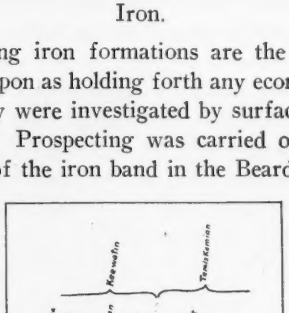

FIG. 8. This illustrates the conditions found at "X" in Fig. 7. The overturning of the fold is clearly shown by the sedimentary iron formation now underlying the fragmental flow top.

although the most detailed work was done near the west end of the formation. No commercial ore bodies were developed although a few small concentrations of iron were located.

Gold.

The gold occurs in fissure veins of high temperature origin. These veins occupy the fault fractures which were formed following the intrusion of the Algoman porphyries. For the most part such fractures are rather straight clean breaks, without much fracturing of the wall rocks, with the result that the veins are narrow and do not occur as stock-works.

The majority of the faults are in the central greenstone area, and here most of them are found localized in the quartzitic Kee-

watin iron formation, and running parallel to its strike. The brittle and relatively narrow iron formation, lying between massive greenstone flows, has apparently been most subject to fracturing. Where vein filling has taken place in such fractures, the wall rock (iron formation) is usually well mineralized with sulphides and commonly carries gold. It was found that only where quartz veins had intruded the iron formation did the latter carry gold. The quartz veins are seldom as much as four feet wide, but this width is greater where gold extends into the wall rock. Veins also occur in the greenstones and the Timiskaming sediments, but they are not as numerous as in the iron formation.

The gold is accompanied by arsenopyrite, pyrite, pyrrhotite, chalcopyrite, sphalerite, galena, native copper, and tourmaline. In some veins one or more of these minerals are plentiful with others lacking; no one vein was found containing them all. The gold occurs as small scales and nuggets in cracks in the quartz.

Origin of the Veins.—As has already been demonstrated, the Algoman intrusives show evidence of having arisen from a differentiating magma. The end product of this process was a silicious sub-magma containing the mineralizers and the gold. The faulting which occurred shortly after the consolidation of the Algoman porphyries formed the openings through which the quartz-bearing solutions came, and in which the veins are now found.

The occurrence of the gold as small flakes in the cracks in the quartz suggests that the gold and silica were not introduced at the same time. This idea was put forward by Spurr [8] for the Porcupine gold veins. He suggested that the quartz solidified first, and a slight subsequent movement caused a small amount of fracturing in the friable quartz. These cracks were the channels of ingress for the auriferous solutions.

In the Beardmore area the gold is found in the quartz veins and the iron formation walls, where the veins cut these rocks. Spurr's hypothesis gives a ready explanation of this, for the vein

[8] Spurr, J. E., "The Gold Ores of Porcupine," *Eng. & Min. Jour.*, Oct. 13, 1923, pp. 633–638.

quartz and quartzitic iron formation would act as a friable unit and the whole would form the host rock for the gold-carrying solutions.

Development Work.—To date very little development has been done in this area, except by prospectors. On only one property—that of the Beardmore Gold Mine Ltd.—has any attempt been made at mining. Here two shafts have been sunk, and it is reported that the vein has been followed to a depth of 200 feet with mineable grade and width. On all the other properties work consists of only shallow pits and trenches put down by the prospectors to uncover the surface of their veins.

ACKNOWLEDGMENTS.

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THINNED POLISHED SECTIONS.

A New Technique for the Investigation of Ores in Thin Slices.

J. D. H. DONNAY.

Both thin sections and polished surfaces have been used in the investigation of ores. It was soon realized that the textural relationships of the minerals to one another were better displayed in polished surfaces than in thin slices. This is especially important when one has to ascertain the relations between opaque ore minerals and transparent gangue minerals.[1] The very poor results obtained from the examination of opaque minerals in thin sections and the great difficulty encountered in the determination of transparent minerals in polished surfaces have led previous investigators to adopt different schemes, which are briefly summarized here.

SAWN SECTIONS.

The chip of rock is sawed in two parts. One of them is used to make a thin section, the other is polished. This method has become standard and has been widely adopted by most foreign and domestic firms which make thin sections on a commercial scale. It gives good results in many cases but is totally inadequate when the ores dealt with are of the disseminated type, occurring in minute stringers and specks throughout the rock. The two sections actually examined are too far apart; the path left by the saw is of a much greater order of magnitude than the microscopic features to be studied.

[1] This point was brought out by C. F. Tolman and A. F. Rogers in their joint paper "A Study of the Magmatic Sulfid Ores," Stanford University Press, 1916, pp. 75–76.

Quoting them: "The relations of the opaque minerals, as a group, to the transparent minerals, are shown more accurately in polished surfaces than in thin sections, and the relations of the transparent minerals to each other are sharper when viewed with the reflecting microscope than with the polarizing microscope."

POLISHED THIN SECTIONS.

These sections were introduced by Tolman and Rogers.[2] They are made like ordinary thin sections, except that they are not protected by a cover glass, after having been reduced to the required thinness, but are polished instead. The polish plays the rôle of the cover-glass and affords good visibility of the transparent minerals in transmitted light. The section can thus be viewed both in reflected and in transmitted light.

The disadvantages of these sections are the following. They are difficult to make; the edges of the mounting-glass must be beveled and their corners rounded, previous to the polishing of the chip, in order not to tear off the cloth of the revolving lap. This preparation of the mounting-glass ought to be done before mounting the section, otherwise the latter might be partly detached from the glass by the vibrations produced by the grinding of the corners. Special contrivances must be devised to hold the section against the rotating wheel during the polishing. The choice of the cement depends on its melting point, which ought to be less than that of the mounting medium (Canada balsam). Sealing wax, for instance, is unsatisfactory. It is difficult to get the section out of its sealing wax holder without breaking the glass or else melting the Canada balsam. A skillful craftsman might succeed in pressing the thin section directly against the revolving lap with no other means of holding it than his nails. The chances of losing the section while making it are always great. The life of a polished thin section is short; it tarnishes quickly and must be repolished for every subsequent examination. It cannot be repolished indefinitely on account of its limited thickness. The polish that can be obtained on such surfaces is not as good as on ordinary polished chips, because the thin slice of rock is not sturdy enough to withstand the rough treatment of polishing. Often the harder minerals chip off, thus obliterating the original textural relations.

To obviate these disadvantages, the writer has devised another

[2] *Op. cit.*, p. 75.

type of combination sections which he has applied to the investigation of disseminated copper ores.[3]

THINNED POLISHED SECTIONS.

The chip is polished first. It is then mounted on glass (with the polished surface against the mounting-glass) and ground down to the standard thickness of .03 mm. The thin slice is transferred onto a cover-glass, so that the polished side now faces the cover-glass. The covered section is finally remounted on another mounting-glass.

The examination of the polished surface in reflected light, through the cover-glass, is considerably hindered by internal reflections in the glass cover, which blur the contacts between the minerals and prevent satisfactory focusing. The difficulty is overcome by using oil immersion lenses. In this case, the three different media intervening between the polished section and the lens (*i.e.*, Canada balsam, cover-glass, and cedar oil) have approximately the same refractive index and it is possible to obtain a perfectly sharp focus. The microscopic equipment should of course comprise low-power oil immersion lenses (8 mm. lens, for instance). The limit of possible magnifications is controlled by the thickness of the cover-glass, which should consequently be chosen as thin as possible.

The polishing processes undoubtedly produce overstrain in the superficial layer of the section. This results in a network of fine cracks which sometimes appear on the edges of the slide, in the softer metallic minerals (such as bornite and chalcopyrite), after completion of the thinning process. The question of the thickness of the layer in which a "permanent set" is produced by overstrain is still largely a matter of speculation.

In spite of the development of this network of fine cracks, sometimes brought about by the rough treatment to which the specimen has to be subjected, and the impossibility of using very high magnifications on account of the cover-glass, these thinned polished sections compare favorably with the previous combina-

[3] Specimens from the Engels Mine, Plumas County, California.

tion sections. Their preparation is easier and faster. A better polish can be obtained, and also a smaller thickness of the slice. The chance of losing them during their making is practically nil. The life of a thinned polished section is long, for it is protected against tarnishing by its cover-glass and need never be repolished. The hard minerals do not chip off as easily, during the thinning of a polished chip, as during the polishing of a thin section. This fact can probably be accounted for by two reasons: the adherence of the section to the mounting-glass might be strengthened by the polish, moreover the thinning is not as rough a treatment as the polishing.

These sections facilitate the use of oil immersion lenses, as the oil film can be washed off the cover-glass easily after examination. In the case of an unprotected surface, the polish of the section is partially destroyed by the rubbing off of the oil film. It has been the writer's experience that it is necessary to repolish most of the specimens, at least during a few seconds, with black magnetic rouge. The trouble of repolishing makes one reluctant to use oil immersion when it is not required for high magnifications. The use of oil immersion lenses, however, should be extended. It is always beneficial in the examination of polished surfaces, for it enhances the reflecting power of the transparent and semi-transparent minerals. This property was brought out by F. E. Wright (1919) in his mathematical treatment of the subject.[4] It was mentioned again by J. Orcel in 1925.[5]

CONCLUDING REMARKS.

The late Dutch professor, R. W. van der Veen, stressed the value of the reflecting microscope for the examination of transparent minerals.[6] He based the study of the latter on the use of etch figures. This method, requiring chemical reagents, is neither

[4] F. E. Wright, "Polarized Light in the Study of Ores and Metals," *Proc. Am. Phil. Soc.*, vol. 58, pp. 417–18, 1919.

[5] J. Orcel: Les Méthodes d'Examen microscopique des Minerais métalliques, *Bull. Soc. franç. Minéralogie*, t. 48, pp. 272–358, 1925.

[6] R. W. van der Veen, "Mineralografie, ook voor doorzichtige Mineralien," *De Ingenieur*, pp. 731–32, 1922.

rapid nor easy, however valuable it might prove to be in certain particular cases. The identification of transparent minerals in polished surfaces is very unsatisfactory, if attempted by means of the physical properties available for observation in reflected light, such as shape, cleavage, hardness, color, reflecting power, and other optical phenomena. The writer is inclined to believe, with Tolman and Rogers,[7] that transmitted light cannot be dispensed with for an accurate determination of the gangue minerals. Their polished thin sections were the first attempt to combine the advantages of the reflected light for the investigation of textural relationships with those of transmitted light for purposes of diagnosis. The present "thinned polished sections" are offered only as an improvement of their earlier technique.

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[7] *Op. cit.*, p. 75.

THE TIN MOUNTAIN SPODUMENE MINE, BLACK HILLS, SOUTH DAKOTA.

G. M. SCHWARTZ.

THE Tin Mountain Mine is located about seven miles west of Custer, S. D., in the southeast quarter of Section 26, T3 S, R3 E. The deposit is on a ridge at the junction of two creek valleys near the western Paleozoic escarpment which faces in towards the pre-Cambrian center of the Black Hills uplift. The mine is accessible by auto road from Custer.

The deposit is remarkable for its close resemblance to the Etta Mine [1] which has long been the world's largest producer of lithium minerals.

GENERAL FEATURES.

History of the Mine.—The Tin Mountain deposit was originally started as a small open pit on the top of the ridge. As indicated by the name, the pegmatite was examined for tin, but no commercial tin was found and, in fact, cassiterite was not observed on the dump or in the mine, though doubtless small amounts may be found from time to time as in most pegmatites of the region.

In 1927 Mr. James Cessna, Superintendent of the Etta Mine, examined the property while prospecting for new deposits for the Maywood Chemical Company.

Several small masses of spodumene may be observed on the hillside outcrop and in the small pit on the crest. Mr. Cessna also observed that woodchucks had removed decomposed spodumene in digging dens in the somewhat altered portions of the pegmatite. On this basis Mr. Cessna purchased the property for his company and in 1927 active exploration began with the re-

[1] Schwartz, G. M., "Geology of the Etta Spodumene Mine, Black Hills, S. D.," ECON. GEOL., vol. 20, pp. 646–659, 1925.

sult that commercial spodumene was encountered almost at once. Shipments have averaged about one carload (40 tons) of spodumene per month. One shipment of pollucite ($H_2Cs_4Al_4(SiO_3)_9$) has also been made. Beryl, feldspar and amblygonite are now being sorted for future shipment.

The Mine.—The original exploration of the deposit seems to have been limited to small and irregular pits on the outcrop of the pegmatite at the top of the hill. The work by the Maywood Chemical Company has been entirely underground. A tunnel was run in from the hillside about one hundred feet below the crest of the hill. From this main tunnel several branches have been driven, as shown in Fig. 2. These have served mainly to outline the deposit. From the south drift a fifty-foot shaft has been sunk and a drift extended northward. Ore is being mined at various places from irregular stopes. The material is all hand-sorted and distributed to bins or stock piles of spodumene, feldspar, beryl, pollucite, and amblygonite, the waste going on the dump.

GEOLOGIC RELATIONS.

The Tin Mountain deposit is one of the pegmatites,[2] in and around the Harney Peak granite batholith in the center of the Black Hills uplift. The deposit greatly resembles the Etta Mine but it is on the opposite side of the batholith and very much farther from the main exposed mass of granite, as is shown by Fig. 1. In fact the Tin Mountain deposit is farther out from the main granite mass than any of the sixty pegmatite deposits shown by Ziegler[3] with the exception of the New York Mica Mine.

The mine is in a relatively small mass of pegmatite which intrudes the much metamorphosed mica schists of the area to the west of the Harney Peak Granite. Although nine miles horizontally from the main exposure, a series of small pegmatites and granite masses distributed over the region indicate that the batho-

[2] See Ziegler, V., "The Mineral Resources of the Harney Peak Pegmatites," *Min. and Sci. Press*, vol. 108, pp. 604–608, 1913.

[3] *Op. cit.*

lith lies but a short distance beneath the surface over a wide area surrounding the main outcrop.[4]

GEOLOGY OF THE DEPOSIT.

The pegmatite intrudes the pre-Cambrian schists of the region as an inclined pipe or lens-like mass. The main intrusion apparently disregarded the schistosity, as the schists at the bottom of the shaft have a strike about east-west and a dip of 65° to the

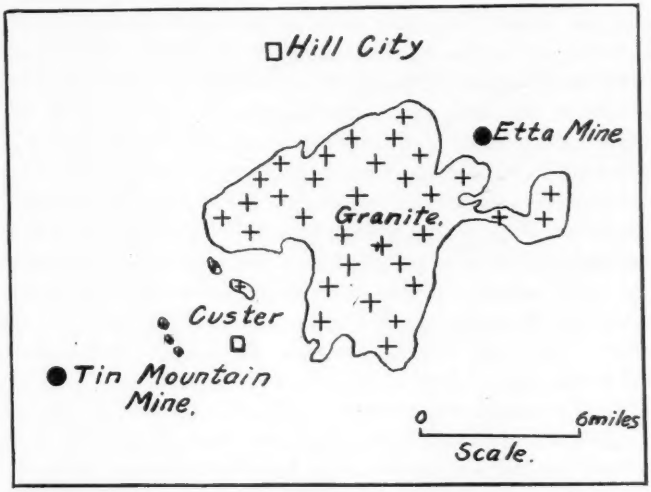

FIG. 1. Sketch map showing the location of the Tin Mountain Mine relative to the Harney Peak Granite and the Etta Mine. The Granite is of pre-Cambrian age and is intruded into schists.

north; whereas the lower plane of contact between the pegmatite and schist in the shaft strikes N. 70° E. and dips 38° to the northwest. At the surface and in the pits, the northwest dip of the pegmatite is evident, and in a raise which reached the surface the upper contact strikes approximately N. 60° E. and dips 35° northwest. The upper contact is decidedly wavy and irregular

[4] Darton, N. H., and Paige, Sidney, U. S. Geol. Survey, Folio 219.

and a thin seam of gouge marks the contact between the pegmatite and the schist. It was impossible to determine with the limited exposures whether this is due to movement or to weathering by solutions concentrated along the contact. The writer inclines to the latter explanation.

The lower contact of the schist and pegmatite is also exposed on the south side of the hill perhaps 75 feet from the crest. The pegmatite apparently did not extend along the strike very far as it is not found on the opposite sides of either of the valleys that skirt the ridge. The exact form of the pegmatite body cannot be determined in the present stage of development. The dip and strike of the contact of pegmatite with schist was observed at the bottom of the shaft and in the raise to the surface (Fig. 2). These corresponded and suggested a dike-like mass dipping in to the hill to the northwest and extending the width of the ridge east and west a distance of perhaps 300 feet. Mapping the underground workings reveals that the structure is not a simple dike, as the contact is too far north and east on the lower level. The outer part of the pegmatite is marked by a finer grained mixture, mainly quartz and muscovite, much like the "mica selvage zone" of the Etta.[5] This zone was exposed near the bottom of the shaft, and in the ends of each of the drifts of the main tunnel. This suggests a possible shape something like that of the Etta deposit. In the drift fifty feet below, this zone was encountered much farther east and south than might have been expected from the exposures on the main level. The shape thus appears to be very irregular, possibly pipe-like or lens-shaped inclined to the northwest; or possibly an inclusion exists on this lower level, and the true wall may not have been reached. Such an included block was found at depth in the Etta Mine, although it was originally thought from drill hole data that the deposit closed in below.[6]

No well-defined contact-metamorphic zone exists, such as surrounds the Etta deposit.[7] The schist exposed at the bottom of

[5] Schwartz, G. M., *op. cit.*

[6] Connolly, J. P., and O'Hara, G. P., "The Mineral Wealth of the Black Hills," So. Dakota School of Mines Bull. 16, p. 243, 1929.

the shaft is a dark, relatively fine-grained hornblende schist. In thin section it proves to be mainly hornblende with some quartz and a little pyrite. It shows none of the characteristics of the typical contact rock of the Etta deposit.

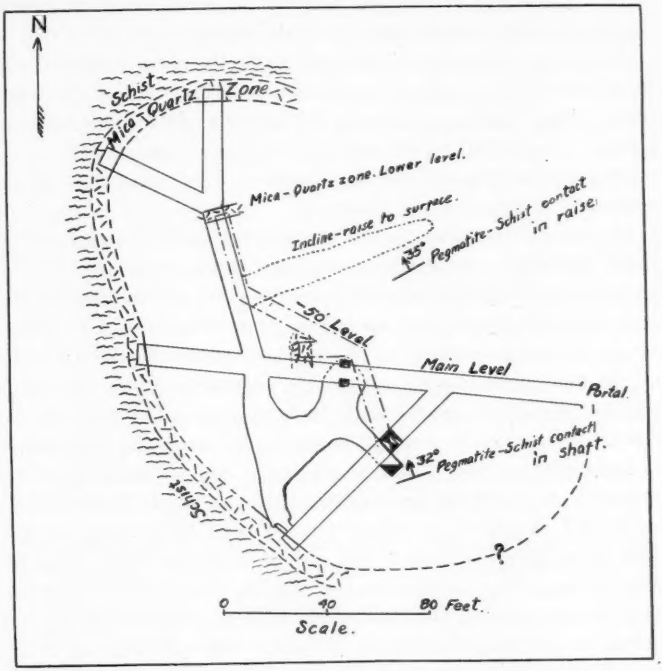

FIG. 2. Plan of the Tin Mountain Mine at the main tunnel level.

MINERALOGY.

The minerals observed in the mine and on the dump are, in approximately the order of abundance: microcline, quartz, spodumene, muscovite, amblygonite, lepidolite, pollucite, beryl, albite, biotite, lithiophyllite, columbite, malachite. There are doubtless

[7] Schwartz, G. M., and Leonard, P. J., Contact action of the pegmatite on schist, *Bull. Geol. Soc. Amer.*, vol. 38, pp. 655–664, 1927.

others which were not observed in the short time spent at the mine. A noteworthy fact is the absence or scarcity of tourmaline, a mineral which is unusually abundant in the Harney Peak Granite and its pegmatites.[8] Most of the characteristic textures of the pegmatites near Keystone are repeated in this deposit, including those assigned to replacement in recent papers.

Microcline.—At the outcrop and above the main tunnel of the mine, microcline occurs as huge masses some of which are quite pure. Some cleavage faces in the upper stope are several feet across. Embedded in this mass of microcline are large crystals of spodumene although not as abundant as in the quartz areas. Euhedral forms were not observed.

Quartz.—Pure white quartz is abundant in the interior of the mass, forming a matrix for huge spodumene crystals. Quartz seems more abundant on and below the main level and in the level fifty feet below, and microcline more abundant in the stope above the main level. Quartz is also an important constituent of the fine-grained outer zone of the pegmatite mass. The general abundance of quartz with high spodumene content in the center of the mass is comparable to conditions in the Etta Mine.

Spodumene.—Spodumene is the most valuable mineral in the deposit. It occurs in the interior of the deposit as huge crystals embedded in quartz or microcline. The crystals vary from a foot in length up to tens of feet and lie in all positions, as in the Etta Mine. The largest observed by the writer in May, 1929, had 30 feet exposed with both ends hidden. The largest crystal mined so far had a diameter of nearly five feet and an undetermined length. It is safe to say that the crystals are comparable in size with those which have made the Etta mine famous. The spodumene, except at the surface, is for the most part very fresh and unaltered in contrast with much of the spodumene in the upper part of the Etta. The fresh spodumene is usually almost pure white although some of it is a pale lilac color. When altered it becomes dark gray or almost black. The spodumene as mined is said to be of somewhat higher lithia content than that from the Etta Mine; this is doubtless a result of its unaltered condition.

[8] Darton, N. H., and Paige, Sidney, *op. cit.*

Muscovite.—The outer zone of the pegmatite is made up of muscovite and quartz with lesser amounts of other minerals. Muscovite is also found as larger masses in the body of the pegmatite but is not abundant. Masses of greenish colored muscovite with a peculiar structure are also found. These may be intergrown with quartz and seem to be composed of small flakes of muscovite (5 mm.) built up to form a prismatic structure in which the prisms radiate out from the center.

Amblygonite.—Amblygonite is fairly abundant at places in the mine. Some masses up to three feet across were noted in the stopes. At places quartz seemed to be replaced by microcline, amblygonite and muscovite. In some place the amblygonite seems to form almost euhedral crystals by replacement. The mineral is sufficiently abundant to warrant sorting out for shipment.

Lepidolite.—The lithia mica, lepidolite, occurs as relatively fine-grained masses similar to its occurrence in the pegmatites around Keystone. It is not always possible to distinguish between lepidolite and muscovite in hand specimen, but in general the purplish colored, fine grained aggregates are lepidolite; whereas greenish or transparent masses are muscovite.

Pollucite.—Connolly and O'Hara [9] have noted the occurrence of pollucite in the Tin Mountain Mine and describe it as follows:

> The pollucite of the Tin Mountain Mine is quite different from that found elsewhere. Instead of being clear and colorless as is usually the case, it is translucent to opaque, very fine-grained and white in color. It is not easily recognized by visual inspection. It was first discovered by making spectroscopic tests of many samples. Its identity as pollucite is shown in the following analysis made at the Mining Experiment Station of the School of Mines by Mr. Charles Bentley, and also by its optical properties, isotropism, and index of refraction.

SiO_2	47.88
Fe_2O_3	0.14
Al_2O_3	17.96
CaO	01.04
MgO	00.38
Cs_2O	23.46
K_2O	01.06

[9] Connolly, J. P., and O'Hara, C. C., *op. cit.*

Na_2O	03.58
Li_2O	00.12
Moisture at 110° C.	00.37
Ignition loss	03.45
	99.44

One piece of pollucite observed was fourteen inches in diameter and suggested a crystal shape, hexagonal in outline. In general, pollucite resembles amblygonite in its occurrence in this deposit.

Beryl.—Considerable amounts of beryl are found in the Tin Mountain Mine as well as in several other Black Hills pegmatites. Much of the beryl is of pure white semi-transparent variety which closely resembles quartz. A clear pinkish variety which resembles pollucite was noted by Connolly and O'Hara.[10]

Albite.—Albite is common but much less abundant than microcline, as is true in the Etta Mine. On the lower level albite seems more abundant and is associated especially with spodumene. Quartz and muscovite are also more abundant there with a corresponding decrease in microcline.

The other minerals listed were not observed with any relations necessitating description. Time did not permit a detailed study of the paragenesis such as Hess and Landes [11] have reported for the Keystone pegmatites including the Etta Mine but, as noted above, the textures seem to be practically the same.

COMPARISON WITH THE ETTA MINE.

The great spodumene deposit of the Etta Mine has long been unique. The discovery of a somewhat similar deposit will prove of much scientific interest for comparison with the original.

The deposits are both related to the Harney Peak Granite batholith of the central Black Hills. The Etta deposit is close to the main outcrop; whereas the Tin Mountain Mine is perhaps eight miles away. This is a surprising distance, but too much

[10] Connolly, J. P., and O'Hara, C. C., *op. cit.*, page 261.

[11] Hess, F. L., "The Natural History of Pegmatites," *Eng. and Min. Jour. Press*, vol. 120, pp. 289–298, 1925. Landes, K. K., "Sequence of Mineralization in Keystone, S. D., Pegmatites," *Amer. Min.*, vol. 13, pp. 519–530, 537–558, 1928.

significance should not be attached to it since the vertical distance may not be great. Possibly the Tin Mountain deposit is located on a cupola of the batholith. The fact remains, however, that of a great group of pegmatites which surround the batholith this deposit is one of those farthest out, as may be observed by comparing Ziegler's map [12] of the deposits with Darton and Paige's [13] geologic map.

In size the limited development work on the Tin Mountain deposit indicates that it is comparable with the Etta. The shape is not well determined by development work up to date. The Tin Mountain deposit is more dike-like and much more inclined than the Etta mass, which is plug-like with only slightly inclined walls.

The structures of the two masses are very similar; the outside of the pegmatite in each case is made up of a relatively fine aggregate of quartz and muscovite with lesser amounts of feldspar and other pegmatite minerals.

The full thickness of the outer zone is exposed in only two places in the Tin Mountain Mine. It seems comparable to the same zone in the Etta Mine where it varies from five to fifteen feet in width. The main body of both deposits is made up of an extremely coarse mixture of quartz, microcline, spodumene, and lesser minerals, with the huge spodumene crystals lying like so many logs in all positions. The schist at the contact of the Tin Mountain deposit does not show the peculiar and striking metamorphism so conspicuous in the Etta Mine, where the schistosity is destroyed and a granular texture developed next to the intrusive.

The principal minerals of the two deposits are the same. The known list for the Etta Mine is much larger but this, in part, is doubtless due to the small amount of development and study of the Tin Mountain deposit. The most striking mineralogical difference noted by the writer was the abundance of pollucite in the Tin Mountain Mine, a mineral not noted in the Etta. On the other hand tourmaline, which is especially abundant in the schist

[12] *Op. cit.*
[13] *Op. cit.*

of the contact zones [14] of the Etta Mine, was not observed at the Tin Mountain Mine. Its absence is the more surprising because it is a characteristic essential mineral of the Harney Peak Granite. The distance of the deposit from the main granite outcrop may explain its absence.

The writer is indebted to Mr. James Cessna, Superintendent of the Maywood Chemical Company properties, for permission to study the mine; to Mr. Carl Dutton and several members of the geology field class, of the University of Minnesota, who greatly assisted in mapping the deposit.

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MINNEAPOLIS, MINN.

[14] Schwartz, G. M., and Leonard, R. J., *op. cit.*

DISCUSSION AND COMMUNICATIONS

ZONING IN MICHIGAN COPPER DEPOSITS.

Sir: It was with pleasure that the writer read Dr. T. M. Broderick's "Zoning in Michigan Copper Deposits and its Significance" which appeared in the March–April and May, 1929, numbers of ECONOMIC GEOLOGY. To any one who has ever been in the district, the enormous amount of care and original thought embodied in the paper, and the new light it bears on the genesis of the copper deposits are readily apparent. However, it is not for the writer to praise these phases of Dr. Broderick's article, but rather to emphasize the value of his contribution in the economic sense.

Reduced to lowest terms, Broderick's article indicating that copper deposition may extend over a range of 20,000 feet along the dip of the lode, has far-reaching economic significance.

First, it provides the visiting geologist with a real "yard stick" to measure one of the factors entering into the estimation of the possible extension in depth of a given ore body. It was partly on the basis of Broderick's arsenic ratio that an engineer who was recently called in to examine an old deep mine in the upper portion of the Keweenawan series in the Michigan copper district, recommended the retention of a large investment in this mine even though the official reports of some of the mines situated in the lower portions of the series, several thousand feet less in depth than the mine examined, indicated a discouraging decline in the grade of ore in their bottom levels. Since the date of that engineer's visit, the "deep mine" continues in its development on the lowest levels to disclose more ore of good grade, some of it said to be much better than ever before encountered in the mine. When we note the arsenic content of the so-called "deep mine" we see that it suggests a horizon of mineralization

some thousands of feet above that of some of the shallower mines of deeper zones. It appears then that the find of this ore at the bottom of the "deep mine" is not a geological surprise, and its continuation to great depths seems quite likely.

Secondly, Dr. Broderick's hypothesis opens up interesting exploration possibilities in the upper portions of the Keweenawan series and emphasizes the favorableness of these upper horizons. Naturally, exploration operations can only be conducted in those upper horizons which show on the surface appreciable copper mineralization.

It is upon such regional field work extending over a period of years that the value of economic geological work rests.

R. D. HOFFMAN.

THE SHERRITT-GORDON COPPER-ZINC DEPOSIT, NORTHERN MANITOBA.[1]

IN a paper of the preceding title, by E. L. Bruce, published in the August, 1929, number of ECONOMIC GEOLOGY, the structure of the sedimentary gneisses adjacent to the Sherritt-Gordon deposit is described as synclinal. On page 463 of this paper it is stated: "there is probably a syncline in the sediments to the northeast of the western part of the vein," and on pages 466 and 467: "a minor syncline lies immediately north of the mine. That is, the deposit lies on one limb of this minor fold."

This contribution is forwarded to present evidence that the structure referred to as a syncline is more probably an overturned anticlinal fold. In my geological report entitled "Kississing Lake Area, Manitoba"[2] and on the accompanying map, it is pointed out that in the area surrounding the Sherritt-Gordon deposit, the general trend of the foliation and bedding of the sedimentary gneisses is northwest, and the prevailing dip from 40 to 90 degrees northeast. The sulphide bodies are in beds of gray gneissic quartzite along their contact with beds of a dark hornblende-plagioclase-quartz-garnet gneiss, and as the beds of gneissic

[1] Published with permission of the Director, Geological Survey of Canada, Ottawa.

[2] Canada Geol. Surv., Summ. Rept., 1928, Pt. B, pp. 73–104 B.

quartzite outcrop fairly continuously, they were followed as an horizon marker. From a point south of the central shaft (originally known as the west shaft) westward for over half a mile, the trend of the bedding of the quartzite is from north 40° to north 20° west and the dip is from 45° to 55° northeast. From here north for over three miles, the strike is approximately north and the dip 75° east. The strike there commences to swing to the northeast, and the dip changes from an easterly direction through vertical to a north or reverse direction. Farther northeast the strike of the strata changes gradually through east to southeast and the dip is northeastward. The outward dip of the beds around the end of this fold indicates that it is an anticline with the west and southwest limb apparently overturned. The west ore body is along the overturned limb of this anticlinal fold.

From south of the central or original west shaft eastward for 7,000 feet, the trend of the bedding of the gneissic quartzite horizon is fairly uniformly southeast, and the dip 45° northeast. In the vicinity of the east shaft, the strike changes from southeast to east and the dip steepens from 45° northeast through vertical to 75° south. East of the east shaft the trend of the beds changes from east through northeast to north and the dip from 75° south to 50° east. Farther north and northwest the dip and strike of the beds on the east limb of this fold approximately parallel the beds on its southwest or overturned arm previously described. The strata on the northeast limb of this fold, however, do not appear to continue northward to join the beds trending southeast from the northeast arm of the anticline described in the foregoing paragraph, as northeast of Cree lake, approximately 18,000 feet north of the east shaft, the strike of the beds swings from north to northeast, and around to the southeast, and appears to parallel the strata from the north end of the large anticlinal fold. The anticlinal fold in the vicinity of the east shaft is considered by the writer to be a drag fold developed along the southwest overturned limb of the major anticlinal fold, and the east ore body is just northwest of the nose of this drag fold.

The more detailed discussion with reference to this structure

is summarized as follows in the report of the Geological Survey of Canada, page 84 B:

> The field work already completed indicates that an unusual structure is developed in the gneisses surrounding the Sherritt-Gordon deposit, and observations in other parts of the map-area did not disclose the presence of other similar structures. The outward dips around the ends of the major structure indicate an anticlinal nature, and possibly the structure may be an anticlinal fold with one limb overturned. Although enough detailed information is not yet available to warrant a definite statement of the nature of the Sherritt-Gordon structure, the suggestion is tentatively advanced that the ore body is along a part of a large drag fold developed on the limb of an overturned anticline. The fact that the deposit is along an unusual structure suggests that the search for additional deposits in the sedimentary gneisses should be guided to some extent at least by a study of the structure of the strata.

In discussing the origin of the deposit, Bruce states that any theory of the origin must explain, among other things, the presence of garnet and scapolite in the deposit. The succeeding discussion indicates that Bruce considers all the scapolite and perhaps some of the garnet enclosed in sulphides to have originated through reactions between ore solutions and wall rock. All the garnet observed by the writer in the ore is much older than the sulphides, and is the same variety of red garnet so abundant in the sedimentary gneisses throughout the map-area. The garnet in the gneisses and in the ore is considered to have formed during the recrystallization of the sediments at the period they were regionally metamorphosed to foliated rocks, which was long before the sulphides were deposited, for the sulphide bodies have undergone only very slight deformation. Although scapolite is not known to be abundant in the sedimentary gneisses of the area, it might be expected to be present in recrystallized limey beds. On Reindeer lake to the north and west of the Kississing area, certain beds of sediments within a series somewhat similar lithologically to the gneisses surrounding the Sherritt-Gordon deposit do carry scapolite (Ma_{35} : Me_{65}).[3] These scapolite-bearing rocks are considered to be recrystallized impure limestone

[3] Stockwell, C. H., "Reindeer Lake Area, Saskatchewan and Manitoba," Canada Geol. Surv., Summ. Rept., 1928, Pt. B, pp. 52B–53B.

beds, and, as no sulphide body is exposed nearby, the scapolite here perhaps also was formed by recrystallization of limey sediments during the period of the regional metamorphism of the sedimentary rocks to a complex of gneisses and schists. It would seem that more probably the garnet and scapolite in the ore represent remnants of unreplaced country rock, as do the abundant blebs of quartz, the amphibole and biotite, and therefore do not indicate a reaction between the sulphide-bearing materials and wall rock, as has been described in many localities in association with contact-metamorphic ore bodies. An interesting feature of the Sherritt-Gordon sulphide bodies is the slight evidence of wall rock alteration by the sulphide-bearing materials.[4] The specimens of ore examined microscopically by the writer show no evidence of a widespread silicification or chloritization of the enclosing country rock. All thin sections, however, do carry small quantities of secondary minerals, such as chlorite, sericite, epidote, zoisite, and calcite, but some of these minerals are always present in the gneiss from outside the ore body. As is to be expected, the quartz and feldspar grains of the gneiss along the sheared and mineralized zone are more granulated than they are in the surrounding unsheared gneiss, and more of sericite and chlorite are developed in the shear zone. The only evidence noted of the alteration of the silicate minerals by the sulphide-bearing materials is a narrow fringe of deep green chloritic material along the borders of some grains of amphibole in contact with veinlets of sulphides and the bleaching of the green biotite to a colorless mica, or the alteration of biotite to chloritic material where pyrrhotite, chalcopyrite and sphalerite form a large proportion of the area of the thin section.

J. F. WRIGHT.

GEOLOGICAL SURVEY OF CANADA,
OTTAWA.

[4] Wright, J. F., "Geology and Copper-zinc Deposits of Cold (Kississing) Lake Area, Manitoba," *Bull. Can. Inst. Min. and Met.*, April, 1929, p. 538.

BOXWORK SIDERITE: AN ANALOGOUS OCCURRENCE OF SILICA AND CHRYSOCOLLA.

Sir: In the Mineral Hill District, Pima County, Arizona, the writer has observed a silica boxwork associated with oxidized copper ores which may be of interest in connection with the similar siderite occurrence described[1] in a recent number of ECONOMIC GEOLOGY.

The Mineral Hill Mining District is situated about twenty miles southeast of Tucson, Arizona. The ore deposits are replacement bodies in limestone associated with a granitic intrusion. They are worked almost entirely for copper, though the adjoining San Xavier District yields lead and zinc as well.

The ores are found close to the contact of an intrusive granite stock in Carboniferous limestone and quartzite. The limestones have been almost entirely marmorized or silicified, the purity of the original rock seeming to have determined which process should dominate. The purer limestone has been simply recrystallized, and shaly and impure beds have been silicified.

The rocks of the region have been extensively fractured and at least one fault of considerable vertical displacement is observable. The wide zones of shattered rock associated with these structural features were evidently very permeable to the ore solutions and most of the deposits are confined to these zones or to the immediately adjacent limestone.

The principal metallic minerals are pyrite and chalcopyrite with minor amounts of molybdenite and magnetite. The usual contact silicates form the gangue, together with a little quartz. Garnet is most widespread, with some wollastonite, sericite, epidote, hedenbergite, and other minerals in less abundance.

The type of secondary alteration has varied to some extent. The stable copper carbonates and silicates are the most prominent alteration products, though in some localities the copper has apparently migrated, due probably to the chemically inert character of the silicate gangue. No secondary sulphides have been

[1] Trischa, C., Rove, O. N., and Barringer, D. M., Jr.: "Boxwork Siderite," ECON. GEOL., vol. 24, no. 7 (Nov., 1929).

observed, primary sulphides having been encountered below the zone of oxidation, which extends slightly less than 200 feet below the present surface. Iron has remained close to the surface for the most part as the limonitic minerals, though the intermediate jarosite has been observed.

The boxwork phenomenon to be described differs from that in the Bisbee District in that there is little or no siderite present. Some siderite has been observed, associated with secondary calcite, but never as boxwork.

The limestone is marked by solution cavities and open fissures. In some of these a beautiful boxwork of thin silica plates is found, very similar in appearance and structure to the siderite boxwork described in the paper under discussion. Close examination of the silica plates shows an extremely thin central layer of chalcedonic quartz, colored brown by iron, and two outer layers of crystalline quartz. The plates are often coated with well-developed crystals of secondary calcite.

In some localities, however, the silica structures are perfectly preserved in chrysocolla, which is sometimes in very thin layers, but is elsewhere to be observed as botryoidal masses building up the walls to half an inch or more in thickness. Some of the silica remains as residual cores in the chrysocolla plates, which mineral has evidently formed to some extent by replacement of the silica.

The conditions which allowed the formation of these rather unusual structures were slightly different from those that obtain in the formation of siderite. As is suggested by the authors of "Boxwork Siderite," the structure is probably due to the original jointing in the limestone. But here we are in a region of intense oxidation, rather than of the slightly oxidizing conditions necessary to the formation of siderite.

The silica, as the writer sees it, was derived from the alteration of the silicate gangue and was deposited as chalcedonic quartz along the joints in the limestone. Later, free acid, derived from the oxidation of pyrite and chalcopyrite, dissolved the calcite, leaving the silica boxwork. It was perhaps at the beginning of the removal of the calcite that the crystalline quartz was deposited.

When the ore minerals were present in the limestone, or very close to it, the copper dissolved during oxidation was immediately precipitated as malachite or azurite, which are stable under surface conditions. Thus migration of the copper was inhibited by the chemically reactive limestone.

On the other hand, the oxidation of the copper minerals in the silicate gangue yielded solutions which were free to move, as such gangues are chemically inert, and cannot reprecipitate the copper.

It is believed that chrysocolla forms only in association with the extensive alteration of silicates. In the gangue in question, abundant silicic acid would have been freed both to form the silica boxwork and to combine with the copper as chrysocolla. Possibly the latter mineral began to form as a replacement of the silica plates while they were still in the gel state, but its formation certainly continued after the limestone had been partially removed.

If it is true that the chrysocolla closely followed the first deposition of silica, then it seems reasonable to suppose that the crystalline quartz plates mentioned above represent another phase and were deposited only where there was no copper in solution, either because of its local absence as a primary constituent of the ores, or because of the formation of the carbonates.

It seems to the writer that these structures are analogous to those described from Bisbee, but that the conditions were more highly oxidizing and gave rise to different products. Non-reactivity of silicate gangue, formation of free acid, and abundance of silica in solution must all be invoked to explain the occurrence described. Such occurrences are doubtless common, but they have received little attention in the literature, and there has been little attempt to explain them.

EDWIN B. ECKEL.

UNIVERSITY OF ARIZONA,
TUCSON, ARIZONA.

REVIEWS

Mineralogy, an Introduction to the Scientific Study of Minerals. By Sir H. A. Miers. Second Edition, revised by H. L. Bowman. Pp. xx + 658, illus. 761. Macmillan Co., London, 1929. Price, $8.50.

The first edition of Miers's "Mineralogy" was issued in 1902. During the twenty-seven years since this date there have been so many advances made in the methods of studying crystals that the incorporation of the results of these studies in the second edition have made the new edition practically a new book. In his preface to the new book Dr. Bowman modestly intimates that the chapter on optical properties has been rewritten, that the section on crystal structures has been somewhat enlarged and a chapter has been added on X-ray analysis.

A careful inspection of the two editions will show that the second edition has been brought up to date, that it includes a great deal of matter not in the earlier edition and that much of the matter of the first edition has been thoroughly reworked. Everything that the author discusses is handled in an exceedingly clear manner, so the reader has little difficulty in following him. The chapters on the optical properties of crystals and their intimate structure, including theories of crystal structure and the use of X-rays in the determination of its character, are particularly worthy of approbation. They are not only clearly written but well illustrated with excellent figures that really help to explain the text.

About one half of the book is occupied by the general portion. The rest is devoted to the description of minerals. Only the most important occurrences are described, and these only briefly. The major part of the description is devoted to the discussion of the physical and chemical properties of the different species, and in many instances their crystal structure is explained. In this portion of the text are also many instructive figures, most of which illustrate the forms of crystals and their internal structures. The relations of closely similar substances are discussed in some detail, as are also the reactions of polymorphous forms to one another.

In short, the volume is a scientific treatise on minerals, which is very different from the ordinary text-book. It is readable, philosophical and modern in its treatment. It makes no pretence to describe all mineral species, but limits its descriptions to those of scientific or economic im-

portance. Three appendices list (1) the best known minerals classified according to composition, (2) the transparent and translucent minerals in the order of their mean refractive indices, (3) according to their birefringences, (4) according to the values of their optical angles and, finally (5) all minerals according to their specific gravities. A good index concludes the volume.

In the opinion of the reviewer the book is the most modern textbook of mineralogy on the market. It is of value not only to mineralogists, but also, in an equal degree, to chemists and physicists.

W. S. BAYLEY.

The Accuracy of Relative Gravity Measurements with Eötvös Torsion Balance (Die Genauigkeit der mit der Eötvöschen Drehwage durchgeführten Relativen Schwerkraftmessungen). By KARL OLTAY. Geodät. Arbeit. der Baron R. V. Eötvös, *Geophys. Forsch.* III, Budapest, 1928.

A series of 15 stations beginning with Potsdam and Budapest and ending with Budapest and Potsdam were occupied in the period August, 1908–January, 1909. The intermediate stations were all at points which had been connected by Baron Eötvös with torsion balance traverses. The observations were made with an invariable pendulum of the standard 4 pendulum type of intrument of the Geodetic Institute, made by Stückrath at Berlin–Friedenau. The observations at each of the field stations lasted 1 to 3 days with one exception; 2 or 3 times determinations were made; 4 to 8 series of pendulum observations were made; the error of determination of the elevation of the instrument above mean sea level ranged from 0.30 meter to 1.10 meters with the exception of the Arad and Baja stations where the elevation was known more accurately and averaged about $\pm$ 0.8 m., which would cause an error of $\pm 0.25 \times 10^{-3}$ dynes. No topographic correction was applied. The values for $\triangle g$ were taken from Eötvös' "Report on Geodetic Observations in Hungary, especially Observations with the Torsion Balance," Budapest, 1910. The differences in $\triangle g$ as determined by the torsion balance and by the unvariable pendulum were: Kuvin-Hidegkut 12 km. 0.001, Livada-Kuvin 9 km. 0.001, Pankota-Livada 13 km. 0.004, Kuvin-Arad 20 km. 0.000, Pankota-Arad via Kuvin 42 km. 0.005, Pankota-Arad via Kurtics 50 km. 0.000 dyne.

Oltay concludes that if the stations are close enough together and if the terrane is rather flat, the measurement of $\triangle g$ with the Eötvös torsion balance is as accurate as with the invariable pendulum.

DONALD C. BARTON.

The Gypsum Resources and Gypsum Industry of New York. By D. H. NEWLAND, N. Y. State Mus. Bull., No. 283, 1929, 184 pages, 59 figures. (Dec.)

This is a notable contribution on an important non-metallic of New York State. The great strides made in the last few years in the gypsum industry have been almost phenomenal. In 1926 the tonnage is estimated to be one and three-quarter millions, and valued at about sixteen and three-quarters millions of dollars. Mr. Newland is eminently fitted to present the gypsum resources and the commercial and technical problems.

The report gives the statistics of production and imports of gypsum, the physical and chemical properties of gypsum and anhydrite, and the character of the various products produced from the crude rock.

Under the heading of General Geology of the New York Gypsum Deposits his tabulation follows closely that of Hartnagle, 1903, where the Salina beds are stated to be composed of limestone, shale, salt, gypsum and anhydrite but without the subdivisions such as Camillus, Syracuse, Vernon and Pittsford, terms which I myself have found difficult to use. He includes the term Cobleskill limestone but in the tabulation does not include the Bertie. Newland furthermore accepts Hartnagle's correlation of the Shawangunk grit and the High Falls shales. He states "Our knowledge of the wide development which the Salina here shows has come largely through the work of Hartnagle whose conclusions derived from stratigraphic evidences have been fully confirmed by study of newly discovered fossil-bearing sections." Newland regards the term "Camillus shale" as something of a misnomer. A better designation is "Camillus beds." In speaking of the salt which lies beneath the gypsum, Newland states "like the gysum and anhydrite the salt occurs over a considerable range, no single deposit being continuous for any great distance, but is distributed among many seams that lie at varying levels and variable distances from each other in the same level."

The red color of the Vernon shale Newland attributes to a small content of ferric oxide. In the green shale of the Vernon the iron is stated to be in ferrous condition. "The difference may be explained by the more advanced weathering which the constituents of the red shale experienced before deposition, for long-continued exposure to the atmosphere results in thorough oxidation of the iron compounds. . . . It does not appear to be necessary, as some geologists contend, that the climate be dry or arid, for red soils are common in the states south of the glaciated country."

The chapters on the chemistry of gypsum and anhydrite are especially fine and constitute the best statement regarding these problems I have seen outside of the more technical chemical journals.

This report is an admirable one from an industrial and commercial

standpoint, but much detail regarding the stratigraphy and paleontology has not been revised as I believe it could have been done with profit. Petrographic studies in the Camillus I am sure would bring to light many additional facts. The Camillus is a much neglected subject.

HAROLD L. ALLING.

Fusit: Vorkommen, Entstehung und praktische Bedeutung der Faserkuhle (fossile Holzkohle). By O. STUTZER, K. A. JURASKY, A. DUPARQUE-LILLE, TH. LANGE-BEUTHEN and others. Pp. 139, figs. 31, tables 58. Ferdinand Enke, Stuttgart, 1929. Price, 14 Marks.

This is the second publication in the series on the geology of fuels that is being issued under the editorship of Dr. Stutzer of Freiberg. It deals with the nature and origin of fusite, fusain, mineral charcoal, or mother of coal. The authors have collected significant facts on the composition and occurrence of fusite, on processes that are known to produce charring of wood, hay and other plant substances, have studied types of fusite under the microscope and have concluded as a result of their studies that the manner of origin of the material has not been determined. Jurasky declares that it is impossible to conceive of charcoal having been deformed to such an extent as fusite fragments in coals are known to be, and consequently declines to believe that the fragments were ever charcoal. They must have been in a more or less pasty condition when deformed.

The book contains much information on the chemical and physical characters of fusain and concludes with a summary of the views of Bode, Gothan, Jeffrey, Petrascheck, Pietzsch, Potonié, Stach, Weithofer and White on its nature and origin. It is well illustrated with microphotographs illustrating the structure of fusain.

W. S. BAYLEY.

Determinate Mineralogy. By PROF. H. C. DAS GUPTA, Presidency College, Calcutta, India.

'Determinate Mineralogy' is a handy volume of neatly arranged matter pertaining to the ready identification of minerals. The first four chapters, though brief, are well written and form a complete and excellent introductory to the study of practical mineralogy. The classification of the minerals according to their specific gravity and hardness (Chap. 5) is a unique feature in this book and should prove most helpful to students preparing for examinations. The last chapter gives thorough descriptions of about 200 important rock-forming and economic minerals. The subject matter and the treatment contained in these pages justify a much better publication and by a well known firm of publishers such as would

give the volume the great publicity it deserves. To the student and to the field geologist, Prof. Das Gupta's book, written with his experience of over a quarter of a century, should be found most useful.

C. MAHADEVAN.

Measurements of Relative Gravity by the Reference Method with Use of Wireless Control of the Coincidence Apparatus. (Relative Schwerekraftmessungen nach der Referenzmethode mit drahtlose Fernsteuerung der Koinzidenze-Apparate.) By ERNST BERGER AND KARL MADER. Gerland's *Beitrage zur Geophysic*, Bd. 21, 4, pp. 355–365, 1929.

An apparatus is described which makes use of wireless control of the coincidence apparatus as well as the recording chronographs. The wireless control is given from the second swings of one astronomical clock common to all stations, and therefore makes possible a synchronous drive of the coincidence apparatus at all the stations, whereby very exact measurements of relative gravity can be made at outlying stations.

The results of the first observations with the apparatus, for the determination of relative gravity between Laxenburg and Vienna, are given.

DONALD C. BARTON.

BOOKS RECEIVED.

By

C. B. HUNT

Analyses of Kansas Coals. U. S. Bur. Mines Tech. Paper 455, Washington, 1929. Pp. 52, figs. 1, map. Price, 10 cts. **Analyses of Maryland Coals.** U. S. Bur. Mines Tech. Paper 465, Washington, 1930. Pp. 87, fig. 1. Price, 15 cts. General geology, mining, preparation, production, distribution, and uses. Detailed treatment of analyses.

Contact Metamorphism of the Rocks in the Pend Oreille District, Northern Idaho. By J. L. GILLSON. U. S. Geol. Surv. Prof. Paper 158–F. Pp. 10, figs. 2, pl. 1. Price, 10 cts. Metamorphism of sediments intruded by late Mesozoic Tertiary granodiorites.

Early Pleistocene Glaciation in Idaho. By C. P. Ross. U. S. Geol. Surv. Prof. Paper 158–G. Pp. 5, figs. 1, pl. 3, map. Price, 10 cts. An early Pleistocene glaciation followed by 1400 feet of valley cutting prior to Wisconsin glaciation; 100 feet of recent erosion.

Dolomites of Western Oklahoma. By G. G. SUFFEL. Okla. Geol. Surv. Bull. 49, 1930 (Feb.). Pp. 125, pl. 11, figs. 12. General geology of region; detailed discussion of dolomites by districts.

Oil and Gas in Oklahoma. Johnston and Murray Counties, by F. A. MELTON. Okla. Geol. Surv. Bull. 40–LL. Pp. 24, map. **Cotton County,** by W. F. CLOUD. Okla. Geol. Surv. Bull. 40–MM. Pp. 21, maps 3. **Mayes, Ottawa, and Delaware Counties,** by H. A. Ireland. Okla. Geol. Surv. Bull. 40–NN. Pp. 37, maps 3. Norman, 1930 (Mar.). Stratigraphy, structure, oil and gas development, future possibilities.

Provisional Geological Map of the Gold Coast and Western Togoland. By SIR ALBERT KITSON. Gold Coast Geol. Surv. Bull. 2, 1928 (Jan. 1930). Pp. 13, pl. 19, map. Price, 2/6. Colored geological map, scale 1 inch to 24 miles; brief description of each formation; pictures of typical exposures.

Tanganyika: Soil and Agricultural Development in Relation to Geology of Northern Kigoma and Southern Bukoba Provinces. By E. O. TEALE. Geol. Surv. Tanganyika Territory, Short Paper 4. Pp. 32, 3 maps and cross sections. Dar es Salaam, 1929 (Feb. 1930). Price, 4 s. Discusses geology by districts and relations to cultural and agricultural developments.

Pre-Illinoian Pleistocene Geology of Iowa. By G. F. KAY AND E. T. APFEL. Iowa Geol. Surv. vol. 34, 1929. Pp. 288, figs. 63, maps 3. General geology, topography and drainage of Iowa; chiefly pre-Illinoian Pleistocene glacial geology.

Titanotheres of Ancient Wyoming, Dakota and Nebraska. By H. F. OSBORN. Two volumes. U. S. Geo. Surv. Monograph 55. Vol. I. contains Chapters I.–VII.; pp. 701, pl. 1–42, figs. 639. Vol. II. contains Chapters VIII.–XI., pp. 703–882, pl. 43–236, figs. 640–797, and index to both volumes. Washington, 1929.

The New England Flood of November, 1927. By H. B. KINNISON. Pp. 56, figs. 6, pl. 13. U. S. Geol. Surv. Water Supply Paper 636–C, 1929 Feb. 1930). Relation of the storm to flood; earlier storms and floods, damage, probability of recurrence.

Surface Water Supply of the San Joaquin River Basin, California, 1895–1927. By H. D. MCGLASHAN. Pp. 67. U. S. Geol. Surv. Water Supply Paper 636–D, 1930 (Mar.). Price, 10 cts.

Surface Water Supply of Pacific Slope Basins in Southern California, 1894–1927. By H. D. MCGLASHAN. Pp. 50. U. S. Geol. Surv. Water Supply Paper 636–E, 1930 (Mar.). Price, 10 cts.

Copies of books mentioned under "Reviews" or under our "New Book List" (see advertisement page) may be purchased through our Journal Bookshop by writing to W. S. Bayley, University of Illinois, Urbana, Ill.

SOCIETY OF ECONOMIC GEOLOGISTS

Ninth Annual Meeting.

The Society of Economic Geologists this year reverted to its early custom of holding an independent meeting in the spring combined with field trips. At the invitation of the University of Virginia and the Virginia Geological Survey, Charlottesville was selected; April 24th and 25th were given to the technical session, followed by visits to the Virginia Alberene Company's soapstone quarries and plant, and the quarry and mill of the American Rutile Company at Roseland.

The first evening in Charlottesville, those attending the meetings were the guests of Mr. and Mrs. Wilbur A. Nelson at a buffet supper at the Farmington Country Club. On the second evening the Annual Dinner was held.

The program follows:

Thursday, April 24, 2:00 P.M.

Read by title:

An Explanation of the Periodicity of Geysers and Gaseous Springs. Jan Versluys.

Hydrothermal Oxidation and Leaching Experiments and their Bearing on the Origin of the Lake Superior Hematite-Limonite Ores. John W. Gruner (Introduced by W. H. Emmons).

A study of the Fluctuation Curves of Two Limestone Springs in Northern Alabama. W. D. Johnston, Jr.

The Miami-Picher Lead and Zinc District. S. Weidman (Introduced by Joseph T. Singewald, Jr.).

Technique of Ore Geology Mapping. Harrison Schmitt.

Presented:

Bedded Hematites of the Unicoi Formation in Virginia. Wilbur A. Nelson.

The Clay Deposits of West Kentucky. Joseph K. Roberts (Introduced by Wilbur A. Nelson).

Virginia Pegmatites. Arthur A. Pegau (Introduced by Wilbur A. Nelson).

A Manganese Deposit in Southwest Virginia. Arthur Bevan.

Some Manganese Occurrences in Virginia with Especial Reference to the Old Dominion Mine. J. S. Grasty (Introduced by Joseph T. Singewald, Jr.).

Genesis of Iron-Manganese Concretions from the Pierre of South Dakota. D. Foster Hewett.

Freezing and Thawing of Soils as Factors in the Destruction of Road Pavements. Stephen Taber (Introduced by Joseph T. Singewald, Jr.).

Recent Test Wells in the Coastal Plain of Virginia. William M. McGill (Introduced by Arthur Bevan).

Some Properties of Limestone as a Reservoir Rock. W. V. Howard and W. W. Love (Introduced by W. S. Bayley).

The Maracaibo Basin of Venezuela. J. Volney Lewis.

Chemical Character of the Ground Waters in the Paleozoic Rocks of Northern Alabama. Margaret D. Foster and W. D. Johnston, Jr.

Genetic Classification of Idaho Ore Deposits. Clyde P. Ross.

Summary of Nitrate Deposits in the United States. G. R. Mansfield.

FRIDAY, APRIL 25, 9:00 A.M.

Gold Ores of North Carolina. H. G. Bryson (Introduced by Joseph T. Singewald, Jr.).

Fissure Vein and Lode Relations in Michigan Copper Deposits. T. M. Broderick.

The Ores of the Northern Rhodesian Copper Deposits. Alan M. Bateman.

A Colloidal Origin of Some of the Kennecott Ore Minerals. S. G. Lasky (Introduced by Alan M. Bateman).

The Copper Ores of New Jersey. J. Volney Lewis.

Iron Mountain, Missouri, Restudied. Edward Steidtman (Introduced by Joseph T. Singewald, Jr.).

Structural Geology of the Conception Bay Region, and of the Wabana Iron Ore Deposits of Newfoundland. Albert O. Hayes.

The Geology of the Commonwealth Mine. Lewis A. Smith (Introduced by Joseph T. Singewald, Jr.).

Revision of Geology at Ouray, Colorado. W. S. Burbank (Read by G. F. Loughlin).

Supergene Enrichment of Lead Ores in the Breckenridge District, Colorado. T. S. Lovering (Introduced by Henry G. Ferguson).

Underground Geology of Western Part of the Tonopah Mining District, Nevada. T. B. Nolan.

Notes on the Origin of Chromite of the Bushveld and Southern Rhodesia. Edward Sampson.

FRIDAY, APRIL 25, 2:00 P.M.

Presidential Address: The Incipient Stages of Rock Metamorphism. M. R. Campbell.

Structural History of the Crystalline Schists of the Blue Ridge Anticlinorium in Central Virginia. Anna Jonas (Introduced by Henry G. Ferguson).

The Origin of the Talc and Soapstone Deposits of Virginia. J. D. Burfoot, Jr. (Introduced by Wilbur A. Nelson).

Petrography of Soapstone from Schuyler, Virginia. H. H. Hess (Introduced by Edward Sampson).

The Rutile Deposits of Amherst and Nelson Counties, Virginia. Clarence S. Ross (Introduced by Henry G. Ferguson).

Metallographic Methods. M. N. Short (Introduced by Henry G. Ferguson).

Vein Quartz of Allegheny District. Henry G. Ferguson.

Salt in the Triassic of North Carolina. Joseph Hyde Pratt and Jasper L. Stuckey (Introduced by Joseph T. Singewald, Jr.).

Cyanite Deposits of North Carolina, Jasper L. Stuckey (Introduced by Joseph T. Singewald, Jr.).

The Mineral Background of the Development of the South. G. P. Grimsley (Introduced by Joseph T. Singewald, Jr.).

Geology as Applied by a State Survey. R. W. Stone.
Antimony Deposits of the World. F. C. Schrader.

Society of Economic Geologists' Dinner at Pretoria.

In connection with the Annual Meeting, it may be of interest to mention an event of the past year, namely, a dinner held in Pretoria during the meetings of the XV International Geological Congress. This dinner was of an informal nature and offered an opportunity for members to become acquainted with each other. The international nature of the Society is well shown by the nationalities of those present. Past-president Ransome presided. The following were present: *Members:* Alan M. Bateman, New Haven; C. P. Berkey, New York; L. L. Fermor, Calcutta; F. F. Grout, Minneapolis; A. L. Hall, Pretoria; John Henderson, Wellington, N. Z.; T. Kato, Tokio; E. B. Mathews, Baltimore; F. L. Ransome, Pasadena; H. C. Richards, Brisbane; E. Sampson, Princeton; H. Schneiderhöhn, Freiberg; F. Schumacher, Freiberg; J. T. Singewald, Jr., Baltimore; F. A. R. Stappenbeck, Berlin; B. Willis, Los Angeles; W. E. Wrather, Dallas. *Guests:* N. L. Bowen, Washington; D. Davidson, Ndola, N. Rhodesia; J. A. MacDonell, Lima, Ohio; H. B. Maufe, Salisbury, S. Rhodesia; P. D. Quensel, Stockholm; P. Ramdohr, Aachen; D. C. Sharpstone, Luanshya, N. Rhodesia.

New Members.

The following have been elected to membership:

W. M. Agar, Dept. of Geology, Columbia University, New York City.
P. F. Boswell, Carlisle Mine, Grant Co., New Mexico.
W. S. Burbank, U. S. Geological Survey, Washington, D. C.
J. E. Gill, McGill University, Montreal, Canada.
James Gilluly, U. S. Geological Survey, Washington, D. C.
W. B. Heroy, 19 Wayne Avenue, White Plains, N. Y.
W. V. Howard, University of Illinois, Urbana, Ill.
C. Y. Hsieh, c/o Chinese Geological Survey, Peking, China.
W. D. Johnston, Jr., U. S. Geological Survey, Washington, D. C.
J. P. Krusch, Prussian Geological Survey, Berlin, Germany.
C. O. G. Larcombe, School of Mines, Kalgoorlie, Western Australia.
M. M. Leighton, Illinois State Geological Survey, Urbana, Ill.
J. G. MacGregor, Mandy Mines, Ltd., Le Pas, Manitoba, Canada.
W. E. McCourt, Washington University, St. Louis, Mo.
T. B. Nolan, U. S. Geological Survey, Washington, D. C.
C. P. Ross, U. S. Geological Survey, Washington, D. C.
H. A. Schmitt, Empire Zinc Company, Hanover, New Mexico.
Otto Stutzer, Bergakademie, Frieberg, Saxony, Germany.

SCIENTIFIC NOTES AND NEWS

Charles H. Behre, Jr., assistant professor of geology at the University of Cincinnati, has resigned to accept an associate professorship in Economic Geology at Northwestern University.

Walter A. RuKeyser has recently returned from five months in Russia, where he served as Technical Adviser to the state asbestos trust, and delivered a lecture before the Department of Geology of Princeton University on "The Consulting Engineer in the Union of Socialist Soviet Republics," which was repeated by request before the Liberal Club of the University.

Sidney Paige has returned from Venezuela.

J. A. Bancroft has returned to Broken Hill, Rhodesia, via London, after a trip to the United States.

A. Broughton Edge has returned to England from Australia, where for two years he has been head of the Imperial Geophysical Experimental Survey, and will soon go to Northern Rhodesia.

Victor Dolmage is chairman of the British Columbia Section of the Canadian Institute of Mining and Metallurgy.

F. B. Plummer gave during March and April a series of lectures at Northwestern University on petroleum geology. At the same time Mrs. Plummer gave lectures on Foraminifera.

Frederick G. Clapp has returned to New York after nearly three continuous years abroad. During this time he was first Petroleum Adviser to the Imperial Government of Persia, and since then has been studying petroleum conditions in Europe and the Near East. During his last year particular study was given to the oil needs and possible oil production of France. Six other European countries were also studied, as well as Egypt, Palestine, Syria, Turkey, Iraq and Persia. While abroad Mr. Clapp was made a member of the Institution of Petroleum Technologists, Geological Society of London, Société Geographique (Paris).

Professor and Mrs. C. K. Leith, of the University of Wisconsin, returned recently from a trip around the world. Professor Leith presented before the World's Engineering Congress in Japan a paper on the world's iron ores in their international relations. He also investigated mineral resources in various countries, particularly Manchuria and India.

A. L. Hall, of the Geological Survey of the Union of South Africa, has been awarded the Murchison Medal of the Geological Society of London.

H. B. Maufe, Director of the Geological Survey of Southern Rhodesia, has been awarded the Lyell Medal.

C. W. Wright has been spending a month in Europe.

William F. Foshag of the Smithsonian Institution and the United States National Museum recently gave a series of lectures at Princeton University, twelve of these being on "The Ore Deposits of Mexico," and one on "The Saline Deposits of the Western United States."

George M. Colvocoresses has opened an office in Phoenix, Arizona, for consulting work in mining and metallurgical engineering.

H. DeWitt Smith of the Newmont Mining So. has returned to New York after an inspection of the company's properties in Peru and Bolivia.

Richard N. Hunt is doing special geological work for the Granby Consolidated, at Anyox, British Columbia, after completing a mine examination in Mexico.

A. D. Bryant, who is mining engineer for the Cerro de Pasco in Peru, is taking a vacation trip to New York and Los Angeles.

E. R. Lilley, of the Department of Geology of New York University, will study political and commercial policies regarding mineral resources in Europe for a year, with the aid of a fellowship under the John Simon Guggenheim Memorial Foundation.

J. W. Steele, formerly supervisor of the Mineral Leasing Division of the U. S. Geological Survey, has resigned to take charge of exploration work in Angola, Portuguese West Africa, for the Sinclair Exploration Company.

Howard S. Bryant, formerly with the Skelly Oil Company at Tulsa, Okla., is now head of their geological department at Wichita, Kansas.

E. A. Wyman is now with the Amerada Petroleum Corporation at Wichita, Kansas, as geologist.

Wallace C. Thompson has left the office of the Sun Oil Company at Wichita Falls and has gone to Tyler, Texas, to take charge of their geological work in East Texas.

Ralph D. Reed is now at Los Angeles acting as chief geologist for the Texas Company in California.

J. V. Danko has left Crown Mines, Ltd., to join the geological staff of Loangwa, Ltd., at Broken Hill, Northern Rhodesia.

Charles W. Henderson of the U. S. Bureau of Mines office at Denver, Colo., is chairman of the Colorado Section of the A. I. M. M. E.

D. C. Jackling has established a Foundation at the Missouri School of Mines to aid worthy students by generous loans and to provide scholarships and special educational features.

Leopold Reinecke, retiring president of the Geological Society of South Africa, delivered his presidential address before the Society on March 17.

The U. S. Geological Survey has designed a new type of dumpy level of great precision for establishing elevations in different parts of the country in connection with their topographic mapping. It has a telescope magnification of 32 diameters and through an ingenious reflector and prism the bubble may be observed at the same time the rod is being read.

The University of Oklahoma, School of Petroleum Engineering, at Norman, Okla., will offer a summer field course in the petroleum industry from June 4 to August 1, 1930. This will consist of the study of operating methods in the Greater Seminole area and the new Oklahoma City oil field. The fee will be $50. Inquiries may be made of H. C. George, Director.

The U. S. Department of the Interior has completed the 13th and 14th test holes for potash in Eddy and Lea counties, New Mexico. Both holes cut several beds of polyhalite of possible commercial value. The Eddy hole also penetrated beds containing langbeinite and sylvite, one 26 inch bed of which at 1675 feet contains 9.6 per cent. K_2O; another 15 inch bed at 1718 feet contains 14 per cent. K_2O. Kainite was recognized in the core.

The Society of Economic Geophysicists has just been organized at Houston, Texas, with D. C. Barton, president; E. E. Rosaire, vice-president; and John F. Weinzierl, secretary-treasurer. This society is as yet not affiliated with other organizations.

The Washington Academy of Science held its 233d annual meeting in Washington on April 16. Dr. Charles B. Davenport gave a lecture on "The Mechanism of Organic Evolution."

The Paleontological and Mineralogical Division of the Amer. Assoc. of Petroleum Geologists has elected the following officers: president, J. A. Cushman; vice-president, C. C. Church; secretary-treasurer, Gayle Scott; editor, R. C. Moore.

The American Association of Petroleum Geologists announces new officers as follows: president, Sidney Powers; first vice-president, R. D. Reed; second vice-president, Marvin Lee; third vice-president, L. H. Lahee.

Daniel Franklin Higgins, Professor of Geology in Lincoln Memorial University, Harrogate, Tenn., died at Knoxville, Tenn., on March 31.

The recently published 20-volume index (336 pages) of ECONOMIC GEOLOGY for 1905 to 1925, compiled by J. M. Nickles, may be obtained for $3.00 from W. S. Bayley, University of Illinois, Urbana, Ill.

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